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Gasification Technology Development and its Implications for Canada

CLEAN ENERGY TECHNOLOGIES

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Canada

Outline

Gasification Technology Development:

- The Big Picture
- Technologies
    - What has been adopted, and where
    - What is available
- Reliability
- Benefits: Gasification *vs.* PC
    - Feedstocks
    - Fossil fuel emissions
- Decision-making Criteria
    - Determining best options
    - Technology selection criteria
- Conclusions
- Sources

The Big Picture for Gasification

- Origins
  - Gasification of coal was developed over 200 years ago for the manufacture of town gas
  - During WWII, Germany produced gasoline and diesel from coal syngas, using the Fischer Tropsch process, while individuals employed small wood gasifiers ('Gasogens')

The Big Picture for Gasification (2)

- Early Commercial-scale Gasification [1]
  - SASOL in South Africa started up in 1955, and now uses 97 Lurgi gasifiers to process 90,000 t/day of coal into 160,000 bbl/day of transportation fuels using the Fischer Tropsch process
  - Dakota Gasification Company (Beulah, ND) started up in 1984, and uses 14 Lurgi Mark IV gasifiers to convert 16,800 t/day of North Dakota lignite into 150 MMSCFD of synthetic natural gas (SNG), as well as fertilizers and chemicals. It also sells CO_2 to Saskatchewan for enhanced oil recovery
  - Eastman Chemical (Kingsport, TN) began gasifying central Appalachian medium-sulphur coal (1,200 t/d) in 1983, using Texaco technology, to produce methanol, acetic acid, methyl acetate, *etc*.

The Big Picture for Gasification (3)

- Modern Commercial Gasification [2]
  - Currently there are >150 operating plants comprising >450 gasifiers
  - Total capacity is ~60,000 MW_{th}
  - Feedstocks include coal (55%), petroleum coke and other residues (32%), and other fuels
  - Syngas is used to produce chemicals (44%), Fischer Tropsch transportation fuels (30%), power (18%), synthetic natural gas and hydrogen

The Big Picture for Gasification (4)

- Currently there are 19 coal gasification projects in various stages of development in the US, the most advanced of which are: [3-5]
  - Duke Energy is replacing 4 PC units from 1944-51 (160 MW total) with a two-train, 632 MW IGCC (GE Energy) at Edwardsport, IN. Commercial operation is expected in 2012
  - ERORA/Tenaska plan to build an IGCC/coproduction unit (GE Energy) at Taylorville Energy Center, Illinois, to produce as much as 525 MW of power, while co-producing pipeline quality SNG, by 2014
  - Excelsior Energy's Mesaba Energy Project (Minnesota) will consist of a 603 MW ConocoPhillips IGCC, with GE gas turbines. Plans include 90% mercury and 30% CO_2 capture. Commissioning in 2014
  - The US FutureGen Project, cancelled during the Bush administration, appears to be being revived under Obama. The original plan was a 275 MW IGCC, incorporating 90% CO_2 capture, and co-production of power and H_2

The Big Picture for Gasification (5)

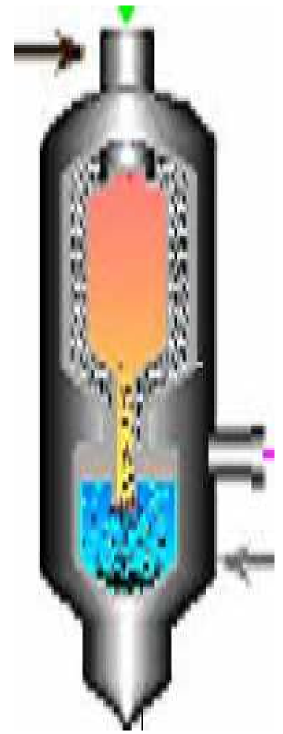
Why gasification? [5]

- Climate change has dramatically raised awareness of the effects of greenhouse gases
  - CO_2 capture/reduction/sequestration will be necessary, and this is easier, cheaper and less energy-intensive in a gasifier
- Activity in Alberta's oil sands continues to be strong
  - A need for cheap hydrogen for upgrading exists—can be satisfied through gasification of low-value by-products (asphalt, petroleum coke, *etc*.)
- Clean SNG can be produced from gasified coal/petroleum coke
- A polygeneration plant can achieve the above, and more
  - Electricity, steam, SNG, chemicals and fertilizers can be produced from cheaper non-petroleum sources, while captured CO_2 can be used for enhanced oil recovery

Gasification Technologies

GE Energy (formerly Texaco Process) [1]

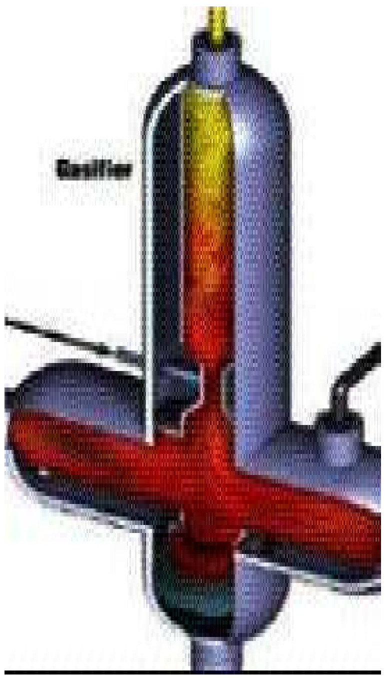
- Coal/water slurry feed
- Oxygen-blown, entrained
- Refractory-lined gasifier
- Works with bituminous coal, petroleum coke, and blends
- Recently acquired Stamet high-pressure dry-feed pump technology; should allow GE gasifiers to be used with sub-bituminous coals in future
- 250 MW coal-fired IGCC at Tampa Electric, Polk County, FL (since September 1996) [6]



Gasification Technologies (2)

ConocoPhillips (E-Gas Process) [1]

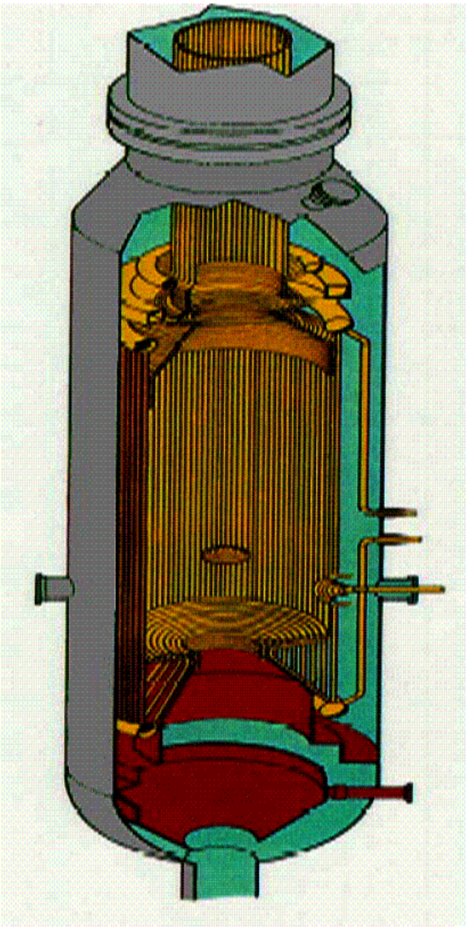
- Coal/water slurry feed
- Oxygen-blown, entrained
- Refractory-lined gasifier
- Can gasify a wide range of feedstocks including bituminous and sub-bituminous coals, petroleum coke and blends
- 262 MW coal/pet coke-fired IGCC at Wabash River, Terre Haute, IN (since November 1995) [6]



Gasification Technologies (3)

Shell Global Solutions Process [1]

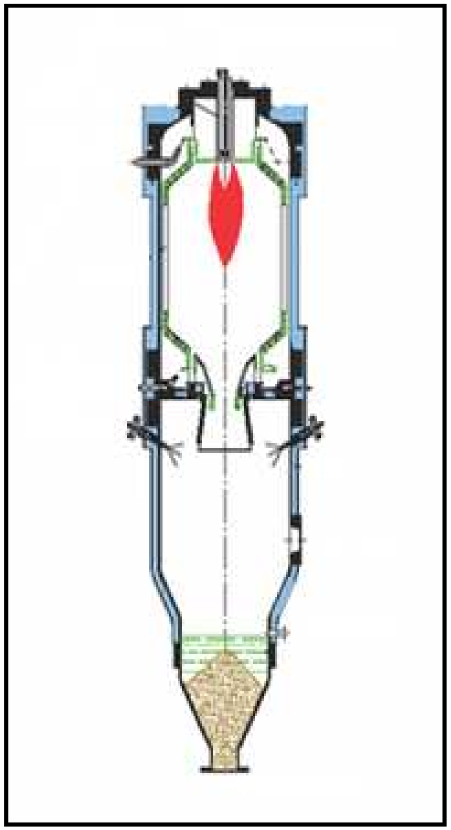
- Dry feed (coal must be crushed and dried)
- Oxygen-blown, entrained
- Waterwall in gasifier
- Can gasify a variety of feedstocks including bituminous and sub-bituminous coals, pet coke and blends
- 253 MW coal/biomass-fired IGCC at Nuon, Buggenum, The Netherlands (since July 1994) [6]
- 4 x asphaltene-fired gasifiers (3,100 t/d) started up in January, 2009 at the OPTI/Nexen, Long Lake, Alberta oil sands upgrader [5]



Gasification Technologies (4)

Siemens (formerly Future Energy) Process [1]

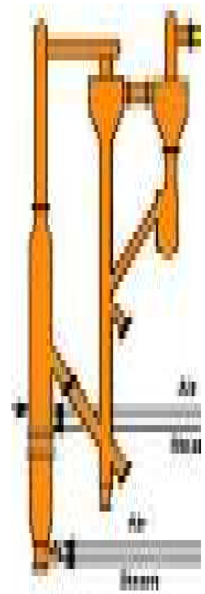
- Dry feed
- Oxygen-blown, entrained
- Waterwall screen in gasifier
- Accepts a wide variety of feedstocks, from bituminous to low-rank coals
- 45 MW lignite/MSW-fired IGCC at Schwarze Pumpe, Germany (since July 1997) [6]
- 385 MW lignite-fired IGCC at Vresova, Czech Republic (start-up 2005) [6]



Gasification Technologies (5)

Kellogg Brown & Root (KBR) Process [1]

- Transport gasifier
- Air-blown
- Based on catalytic cracker technology from refinery industry
- Best on low-rank coals (sub-bituminous and lignite)
- 285 MW low-rank coal-fired IGCC application at Orlando Utilities, Stanton Energy Center, FL, was recently cancelled [5]

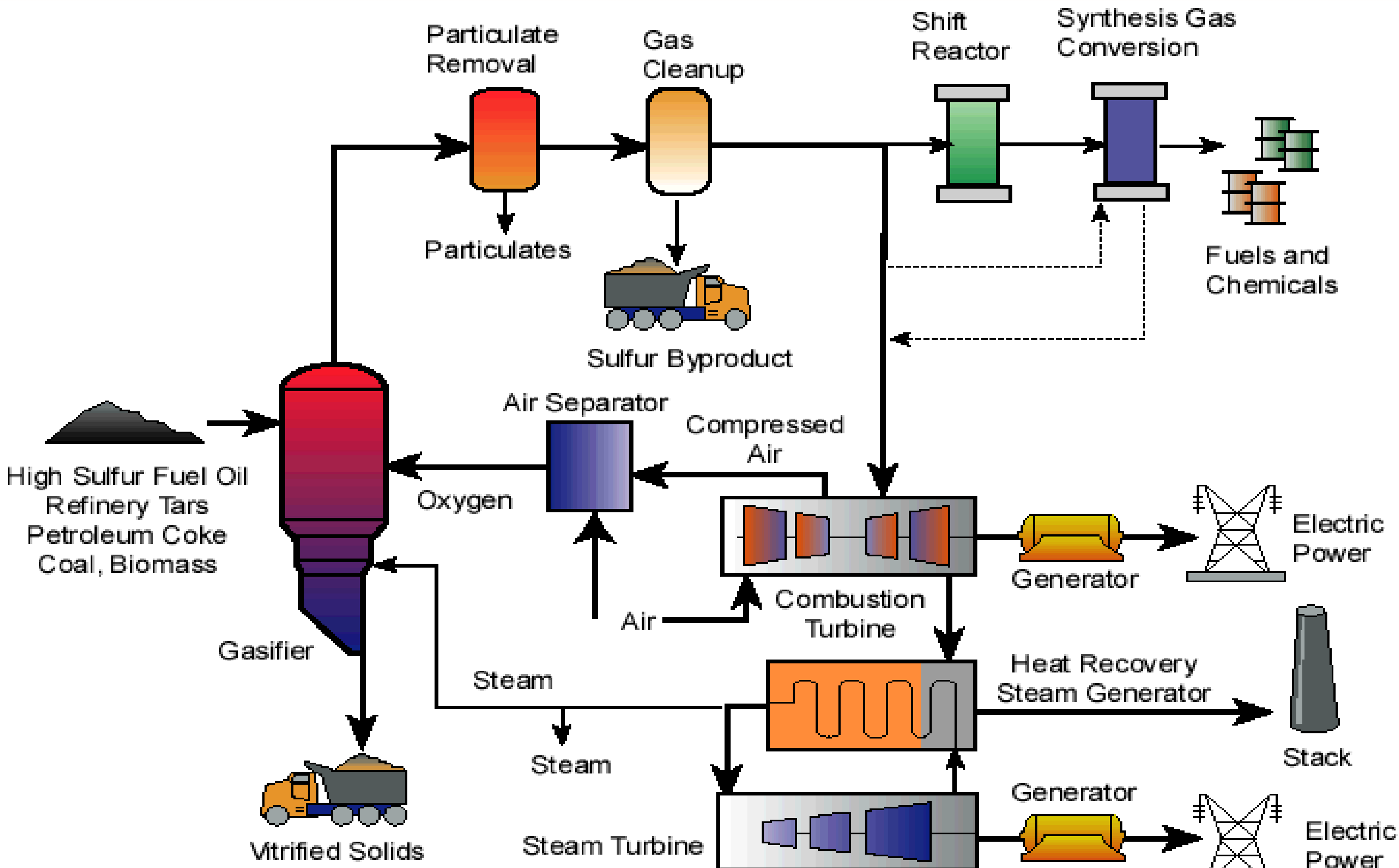


Gasification Technologies (6)

Pratt & Whitney-Rocketdyne (PWR) Compact Gasification System

- Rocket engine technology
- Dry feed, plug flow, oxygen-fired
- High temperature (2760°C)
- 90% size reduction
- 50% lower cost
- 99% availability
- For all ranks of coal/pet coke
- Commercial-scale unit now being designed [7]
- Development agreement signed with ExxonMobil [5]

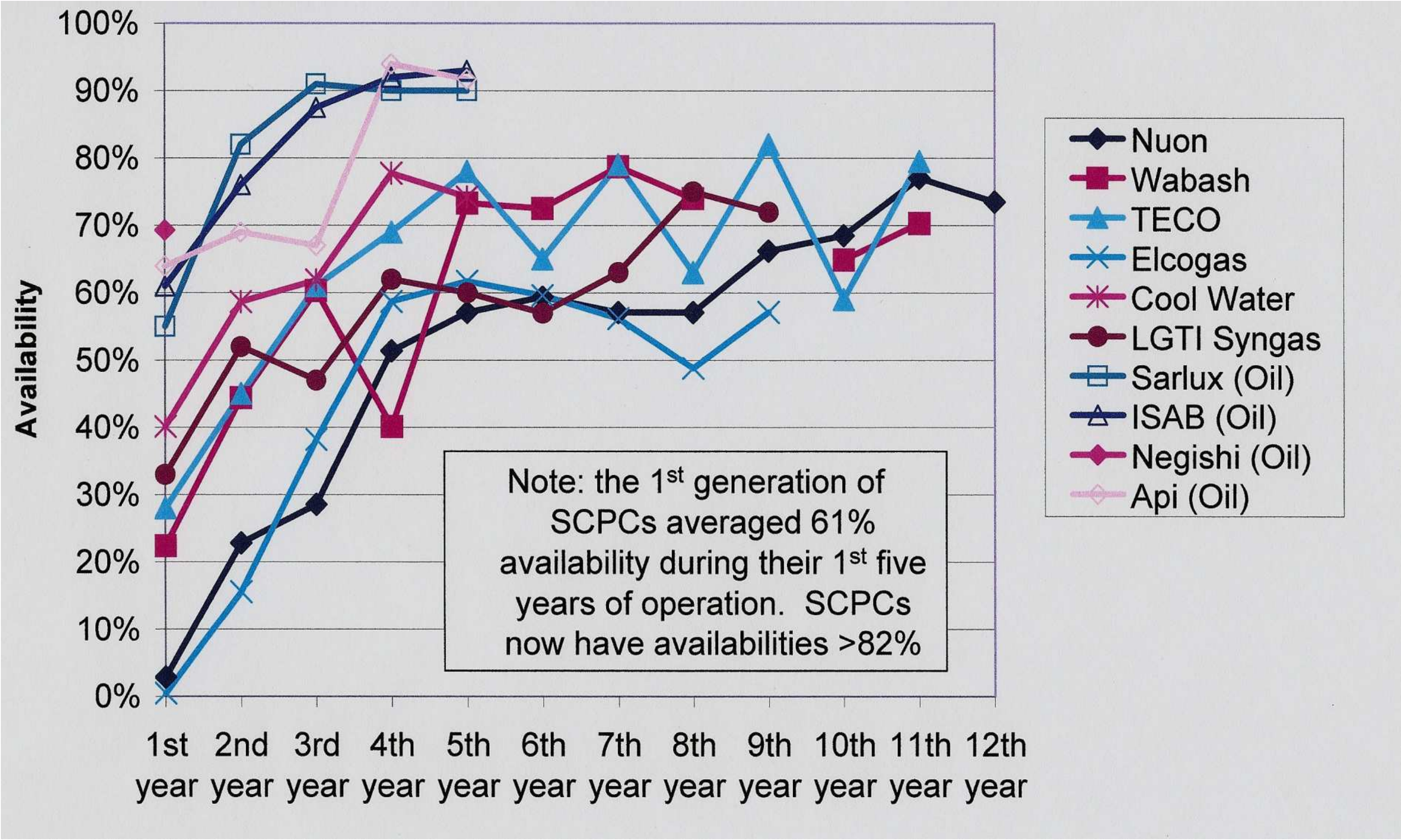
Typical IGCC Schematic



Gasification Reliability

- Gasification is regarded by PC plant operators as a complicated chemical process. This view has been fueled by low availability figures for the large coal-fired demonstration plants
  - Some of the unavailability resulted from contractual obligations to the demonstration sponsors (*e.g*., the attempt to operate hot-gas filters at Polk County, FL)
  - A large proportion of the unavailability was due to combined cycle issues, unrelated to the gasification process (*e.g*., combustion turbine problems at Buggenum, The Netherlands and Puertollano, Spain)
    - Where the air separation unit (ASU) is supplied its compressed air from the combustion turbine, combined cycle problems effectively shut down the gasifier
- Lessons learned from past problems, and current efforts to standardize (as much as possible) the IGCC layout should result in near-future improvements in availability

IGCC Availability [8]



IGCC Availability (2)

- The historical availability graph (from EPRI) indicates that the demonstration coal-IGCCs lag behind supercritical (SC) PC availability for both average over first five years, and mature values
- The oil (bitumen, *etc*.)-fired IGCCs show much improved reliability, with first year availability averaging 62%, rapidly climbing to 90%+ after four years
- These data suggest a close fit between IGCC/gasification and the Alberta oil sands—where waste and low-value feedstocks such as pet coke and resid can be converted into steam, electricity and hydrogen (reducing the need for costly natural gas)

Benefits: Gasification *vs.* PC

- Environmental control
  - Because environmental control processes operate on syngas (pre-combustion) in an IGCC, nitrogen from the combustion process is largely absent, meaning that smaller gas volumes need to be treated—this results in lower treatment cost than for the PC
  - For the same reason, and because gasifiers operate at elevated pressure, CO_2 capture/compression can be achieved at a significantly lower cost
- Environmental emissions
  - Sulphur, nitrogen oxides and particulates coming from an IGCC are at least an order of magnitude less than those from a vintage PC
- Efficiency
  - Gasification/combined cycle can have overall efficiency of perhaps 43%, compared to about 34% for a PC with sulphur and nitrogen oxides control. This results in perhaps 25% lower uncontrolled carbon dioxide emissions

Benefits: Gasification *vs.* PC (2)

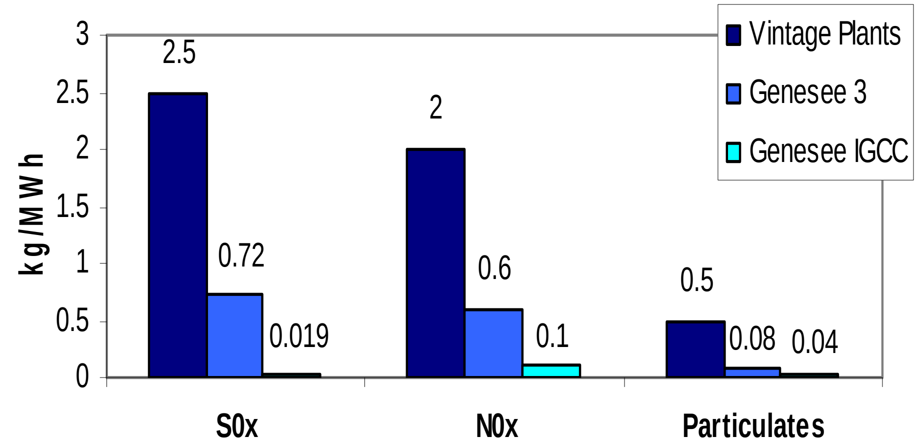
- Gasification produces syngas, which can be easily converted to many valuable products: electricity, steam, hydrogen, ammonia, methanol, other chemicals, SNG, and transportation fuels
- Gasification can utilize a multitude of fuels and blends: coal, lignite, opportunity fuels such as petroleum coke and other processing residues, gas, biomass, and Orimulsion
- Mercury removal in an IGCC plant has been estimated to cost <$0.25/MWh, an order of magnitude less than for a PC plant. Eastman Chemicals has been removing >94% mercury from their Texaco gasifier for more than 20 years

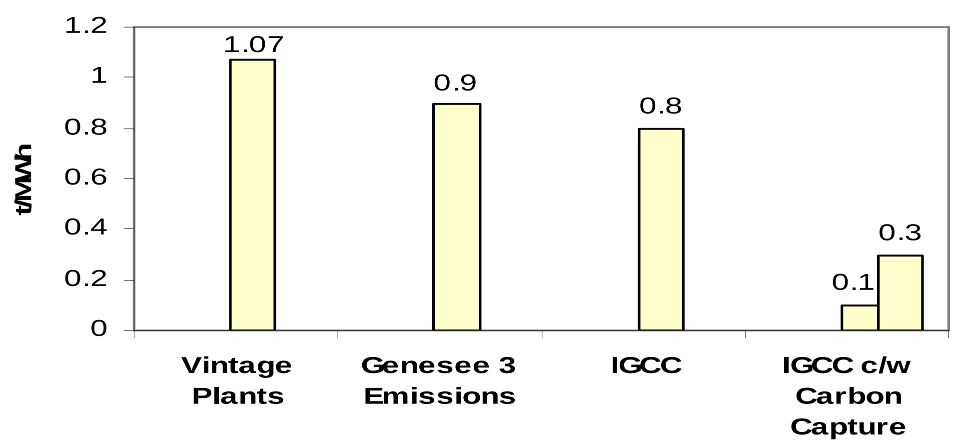
Benefits: Gasification *vs.* PC (3)

- Waste products
  - Slag from an IGCC is inert and can be sold for many uses
  - Sulphur or sulphuric acid from an IGCC has a positive market value
  - Ash and scrubber effluent (gypsum) from a PC may have some minimal value, but in most cases incur a cost for disposal
- Water usage
  - Since IGCCs do not require scrubbers for sulphur capture, water requirements are considerably less (~40%) than for a PC

Emissions Comparison [9]

- These figures are from EPCOR
- The lower graph represents CO_2 emissions. For the IGCC case, two levels of CO_2 capture are indicated
- Note that Genesee 3 is EPCOR's new SCPC
- As shown, emissions are substantially lower for IGCC *vs* PC, and significantly lower for IGCC *vs* SCPC





Decision-making Process

- Best options
  - First and foremost, a crystal ball is necessary to predict whether, and how much, carbon dioxide capture will be necessary such that permitting for the new plant can be obtained—capture-ready plant designs exist, but the cost of converting to carbon dioxide capture in the future is more than if the plant was originally built to capture CO_2
  - The product slate must be determined, based on site-specific needs and market conditions. *E.g*., is hydrogen more valuable in the immediate area, or is there a growing demand for electricity.
  - What fuels are available at the site in the long term? The answer to this question might eliminate certain gasifier types, or strongly point to others.

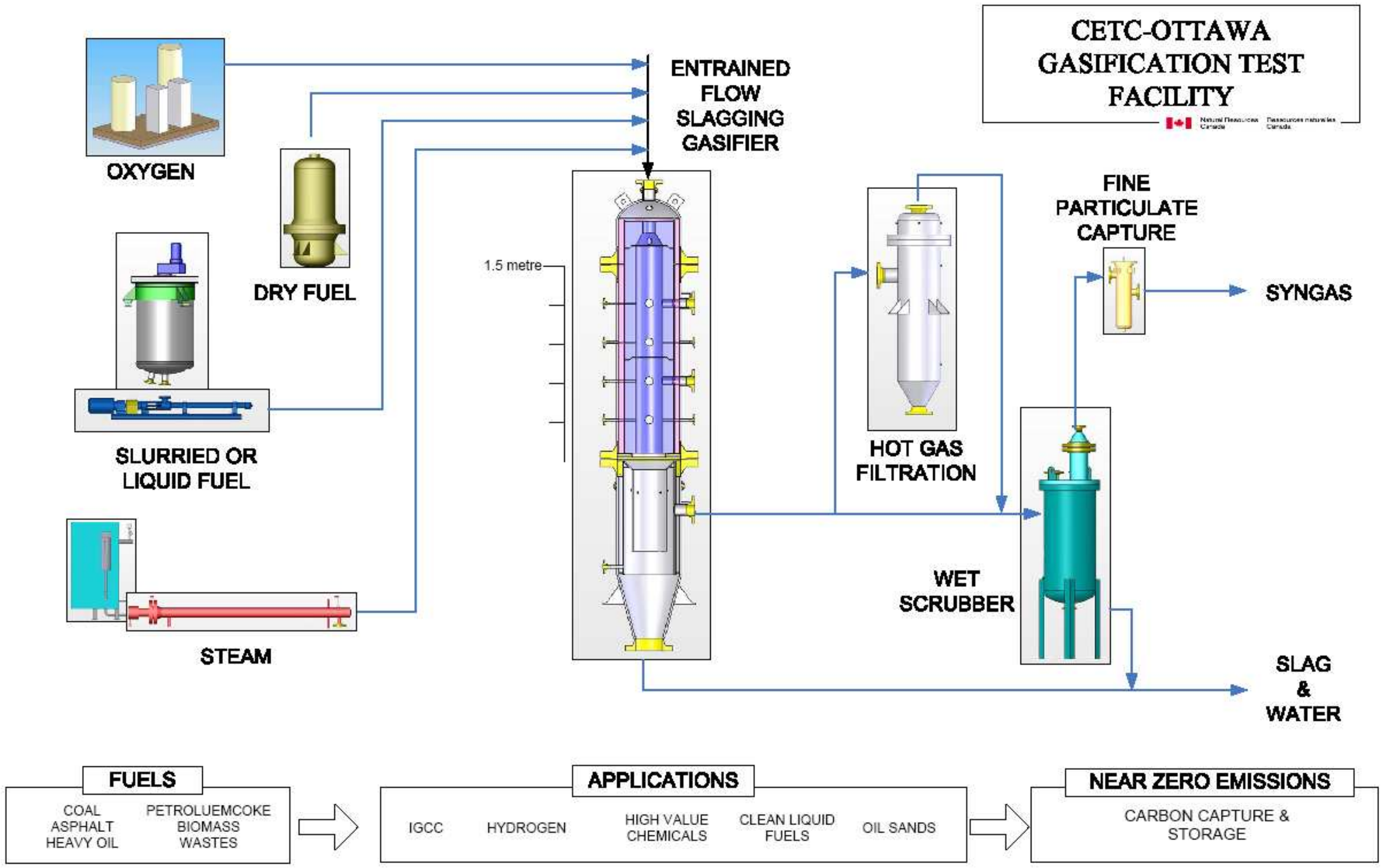
Decision-making Process (2)

- Technology selection criteria [10]
  - Site-specific criteria such as: plant size; number of gasifier trains and spares philosophy (more redundancy improves reliability, but at higher cost); fuels (single or multiple fuels/blends); product slate (what is the market for various products/what are immediate and future needs?); carbon capture—no/yes/how much
  - Technology evaluation: maturity of each technology; attributes of each technology; operating experience with selected fuels and whether technology is capable of gasifying these fuels; availability of pilot plant data or of suitable pilot plant for testing specific fuels
  - Syngas cleanup: particulate removal (filters, cyclones or scrubbers); gas cooling and sensible heat recovery; water scrubbing and sour water treatment; acid gas removal and recovery technology
  - Air separation unit integration with combustion turbine compressor (to supply compressed air to ASU): full, partial or no integration

Decision-making Process (3)

- Studies [5]
  - Canadian Clean Power Coalition (CCPC) has spent nine years and several million dollars studying a number of the previously mentioned factors, with respect to IGCC and oxyfuel combustion, for its members (Canadian and US utilities and coal producers, government agencies and EPRI). This effort appears to be paying off, as two of its members are on the verge of proceeding:
    - Sherritt International is evaluating a project to gasify coal for production of syngas/hydrogen in Alberta. The first phase would involve one gasifier capable of producing 270 MMSCFD of hydrogen. Carbon dioxide would be pipelined to market or sequestered. Sherritt has conducted gasification tests on a number of fuels at the Siemens (formerly Future Energy) pilot plant facility in Freiberg, Germany
    - EPCOR/CCPC are currently completing a front-end engineering and design (FEED) study for a 270 MW IGCC with carbon capture at their Genesee site. If the plant is built, it will provide a unique opportunity for comparison of IGCC and SCPC technologies at the same site. Siemens has been selected as gasification/power system supplier

Gasifier Overview



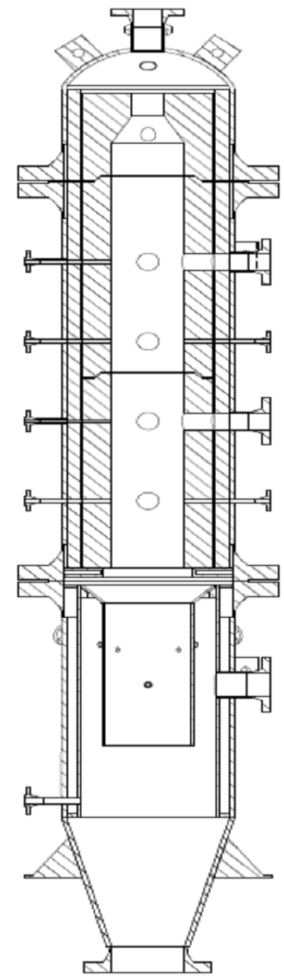
Key Achievements (II) --Gasification

- Entrained-flow slagging gasifier has been upgraded to operating conditions of:
  - Pmax = 2500 kPa
  - Tmax = 1700 ℃
- Capable of gasifying pulverized fuel, fuel-water slurry, or liquids
- Contract with ConocoPhillips ($484 k) is on-going
- CCPC task sharing agreement $7.5 M was signed and CANMET is a member of CCPC committee for Phase III studies
- Coal beneficiation testing work has been initiated with CCPC

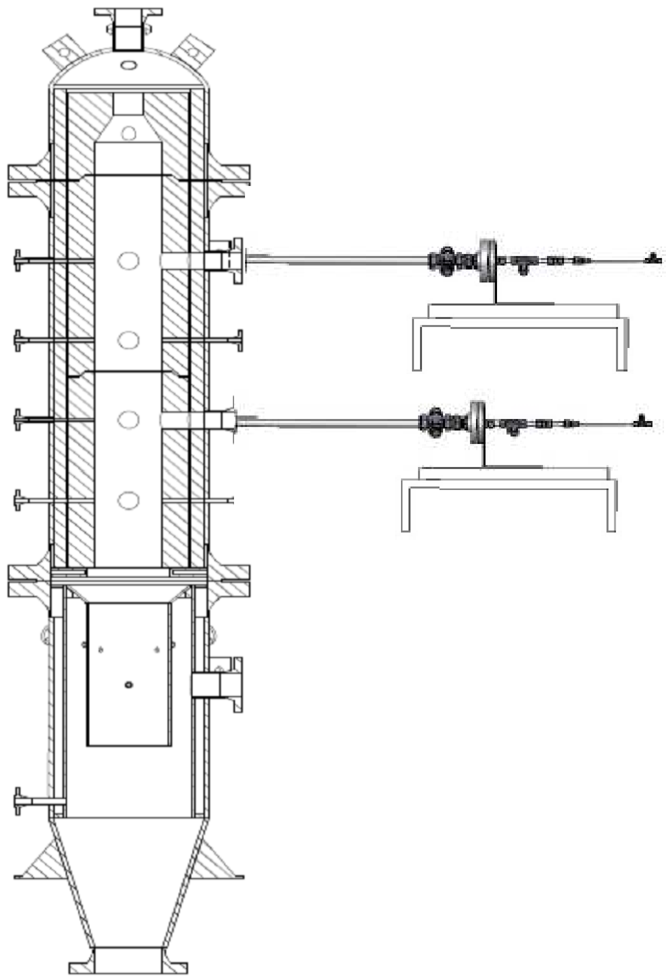
Gasifier Reactor Upgrade

New gasifier constructed at CanmetENERGY to:

- Allow more severe operating conditions (2,000 kPa and 1800°C)
- Provide sampling access points for kinetics studies and new instrumentation development
- Evaluate commercial and prototype refractories for different fuels
- Increase residence time and reduce heat losses to more closely represent commercial operations



Reactivity & Composition – *In Situ*



Sample probes are used for extracting gases, tar, slag and char from the gasifier

Two styles

1. Nitrogen cooled jacket for maintaining sample at elevated temperature
   - Sampling experience with sample maintained at up to 400℃
   - Suitable for tars
2. Direct water quenched
   - Under development and test
   - Positioned with servo driven linear actuator

Will attempt iso-kinetic sampling this year

Conclusions

- Gasification is a mature process (200 years) with >150 operating plants, comprising >450 gasifiers
- Current interest in coal/refinery residue gasification is being driven by volatile gas prices, large reserves of inexpensive coal/residues, the need for vast quantities of hydrogen, and the near-future need to reduce carbon emissions—there are 19 coal gasification projects in various stages of development in the US, and interest is growing in Canada, especially for application in the Alberta oil sands.
- Coal-fired IGCCs lag behind SCPCs in availability; however, bitumen-fired gasifiers rapidly climb to 90%+ availability

Conclusions (2)

- Basic IGCCs generally cost more than basic SCPCs, but they are much more versatile:
  - Cheaper mercury capture
  - Cheaper, less energy-intensive carbon dioxide capture
  - Can operate on multitude of fuels
  - In the polygeneration configuration, can produce number of valuable products such as hydrogen, SNG, fertilizers and chemicals
  - Deep clean-up of SO_x, NO_x and particulates is standard
  - Byproducts are marketable
- Necessary to determine how/when carbon dioxide and mercury will be regulated, and what the long-term value of potential products (electricity, H_2, *etc*.) will be, before making informed decision on building gasifier
- Decision process is not cheap, requiring fuel testing, FEED, *etc*.

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