18th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES

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Gasification:
Converting Low Value Feedstocks to High Value Products

by

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Gasification Process Concept

- Convert low value carbonaceous solid or liquid feeds to a synthetic gas.
- Reaction of feed with oxygen and steam at high pressure and temperature conditions.
- Reducing rather than oxidizing environment in gasifier converts most sulphur to H_2S rather than SO_2.
- Synthetic gas clean up and acid gas removal.
- Conventional sulphur recovery.
- Combustion or further processing of clean synthetic gas.

Historic Overview

1850's - Much of London was illuminated by 'town gas', produced from the gasification of coal.

1881 - First used to power an engine ‘producer gas’.

1887 - Lurgi Gasifier.

1900 - Most world cities had a "gasworks" supplying gas to residents.

1930’s - Natural gas from oil wells began to be used.

1940’s - Fuel shortage in WWII prompted a renewal of gasification research.

1960 - Coal Tested as Fuel for Gas Turbines (Direct Firing)

1970’s - Interest again grew in the possibilities of producer gas, particularly for use in developing countries, US Synfuels program.

1984 - First IGCC Pilot at Coolwater.

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Process Chemistry

- Two Primary Reactions
  - Partial Oxidation (highly exothermic): $C + 1/2\ O_2 \rightarrow CO$
  - Steam Reforming (highly endothermic): $C + H_2O \rightarrow CO + H_2$

Process Chemistry continued

- Secondary Reactions
  - Methanation (exothermic):
    $CO + 3H_2 \rightarrow CH_4 + H_2O$
    $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
  - Water Shift (mildly exothermic):
    $CO + H_2O \rightarrow CO_2 + H_2$
  - Carbon Formation:
    $C_nH_m \rightarrow n\,C + m/2\,H_2$ (cracking)
    $2\,CO \rightarrow CO_2 + C$ (Boudouard)

Cat and Dog Reactions to NH3, COS, CS2, phenols, carbonyls etc etc etc

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The Uglies

- Straight forward chemistry shows product syngas containing CO, H2, CO2, CH4 and H2S.
- But also need consider
  - N2: impurity in O2 plus feed content
  - Ar: impurity in air
  - NH3: N in O2 plus feed content
    - High reaction temperature equilibrium favours N2
  - COS, CS2 etc etc etc sulphur compounds:
    - Traditional amine AGR does not absorb non-H2S but physical solvents do
  - Metal (Fe/Ni) carbonyls: only a few ppm but deposits on hot surfaces (of concern here, GTs), fouls, converts to sulfides and accumulates in AGR solvent, VERY TOXIC

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Uglies continued

- Soot: depending on process a portion of carbon is "unconverted" and forms gas phase soot. Encases ash.
- Slag: in quench type entrained flow reactors, ash and soot is rapidly quenched and forms slag.

World Syngas Production Capacity by Primary Feedstock

Existing Facilities

Feedstock	Plants	Gasifiers	Equivalent MW_{th}	Output MMSCFD	Equivalent MW_e
Coal	28	168	18,150	4,976	9,951
Petroleum	54	129	15,240	4,162	8,323
Gas	24	38	4,533	1,243	2,484
PetCoke	5	5	1,939	384	769
Biomass	5	11	714	194	390
Totals	**116**	**351**	**40,030**	**10,959**	**21,917**

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Operating IGCC Projects

Project	Start	Feeds	Gasifier	GT Supplier	IGCC MWe
Schwarze Pumpe Power	1964	Biomass	Sustec	GE	224
Värnamo IGCC Demo Plant	1993	Biomass	FW PCFBG	Alstom UK	8
Buggenum IGCC Plant	1994	Coal	Shell	Siemens	253
Wabash River Energy Ltd.	1995	Petcoke	E-Gas	GE	323
Vresova IGCC Plant	1996	Coal	Sasol Lurgi Dry Ash	GE	400
El Dorado Gasification Power Plant	1996	Petcoke	GE	GE	45
Polk County IGCC Project	1996	Coal	GE	GE	246
Shell Pernis IGCC/Hydrogen Plant	1997	Resid	Shell	GE	120
Puertollano IGCC Plant	1997	Coal	Prenflo	Siemens	321
Kymijärvi ACFBG Plant	1998	Biomass	FW ACFBG	-	27
Fondotoce Gasification Plant	1999	Biomass	Thermoselect	-	19
ISAB Energy IGCC Project	1999	Resid	GE	Siemens	657
Amercentrale Fuel Gas Plant	2000	Biomass	Lurgi CFBG	-	46
SARLUX IGCC Project	2000	Resid	GE	GE	777
api Energia S.p.A. IGCC Plant	2001	Resid	GE	ABB	287
Chawan IGCC Plant	2001	Resid	GE.	GE	199
Delaware City Refinery	2002	Petcoke	GE	GE	284
Sanghi IGCC Plant	2002	Coal	GTI U-Gas	GE	60
Negishi IGCC	2003	Resid	GE	Mitsubishi	433
ENI Sannazzaro	2006	Resid	Shell	Siemens	1050
ICCT – Yankuang	2006	Coal	OMB	GE	72
Clean Coal Power – Nakoso	2008	Coal	Mitsubishi	Mitsubishi	250

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IGCC Projects in Construction, Start-up & Development Phases

Project	Start	Feeds	Gasifier	GT Supplier	IGCC MWe
Agip IGCC	2006	Resid	Shell	Siemens	250
Thermoselece Vresova SNG	2007	Coal	GSP.	GE	400
Long Lake Integrated Upgrading.	2007	Resid	Shell	GE	560
Brazilian BIGCC Plant	2007	Biomass	TPS	-	37
Fujian Refinery Ethylene Project	2009	Resid	Shell	GE	475
Paradip Gasification H2/Power Plant	2010	Petcoke	Shell	GE	485
Edwardsport IGCC	2011	Coal	GE.	GE	630
Hydrogen Power Project, Carson	2012	Petcoke	GE.	GE.	630
Taylorville Energy Centre	2012	Coal	GE	-	630
Lima Energy IGCC Plant	2013	Petcoke	E-Gas	-	1395
Mesaba Energy Project	2013	Coal	E-Gas	-	-

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Natural Gas Demand by Oil Sands
Supply/Demand Considerations

- Canadian National Energy Board estimates[1]:
  - 3 million bpd oil sands capacity by 2015
  - Equates to 1.9 million bpd new capacity
  - "*…new projects are divided roughly evenly between in-situ recovery and mining, with a little more weight on mining.*"
  - With a demand of 2.1 bcfd natural gas by 2015

(1) Reference: Oil & Gas Journal, 12 July 2006, p. 34

Natural Gas: Supply/Demand Considerations

- Compare this to:
  - – MacKenzie Gas Pipeline at 1.2 bcfd
  - – Total Canadian consumption of ~8 bcfd [2]

(2) Reference: North America Natural Gas Vision, North America Energy Working Group, Jan 2005

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So, What's an Oil Sands Producer to do?

- Business as usual – pay the price
- Process modification/improvement
- Improved insitu Processes
  - Fireflood, VAPEX, Hybrid VAPEX – SAGD, Electric Heating, etc.
- Export bitumen as dilbit or synbit
- Alternative fuel source
  - Coke/Coal
  - Residues/Asphaltene

} GASIFICATION

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Why Gasification?

- Supply of Natural Gas
- High Cost of Natural Gas
- It fits – primary upgrading/resid conversion processes produce low-value by-products
  - Low value by-products → high value H_2 / FG
- Growing importance of SAGD
  - Needs steam
- In Oilsands operations coke is **stored**, not disposed, in mines
- The Product Value Chain
  - Needs hydrogen

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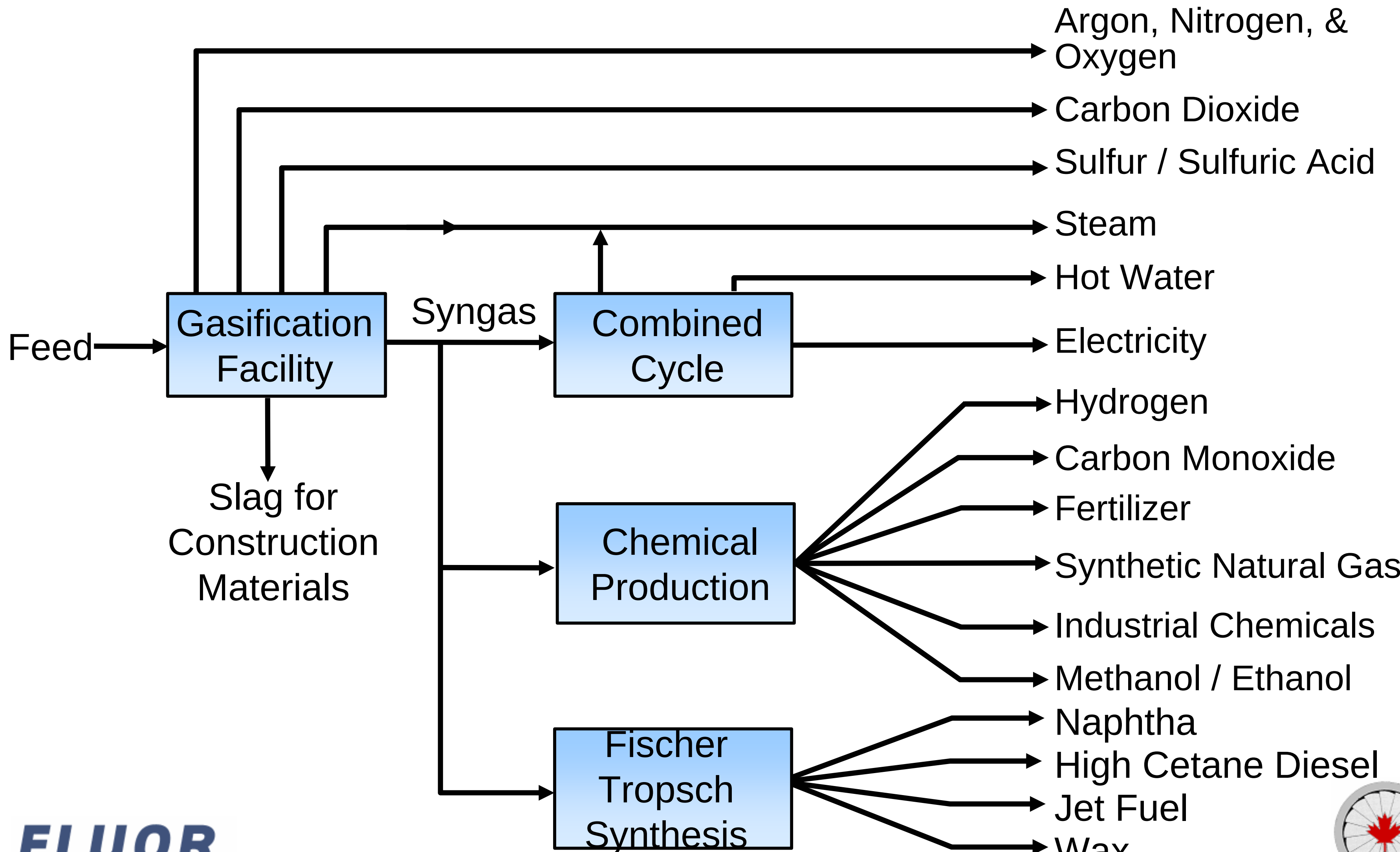
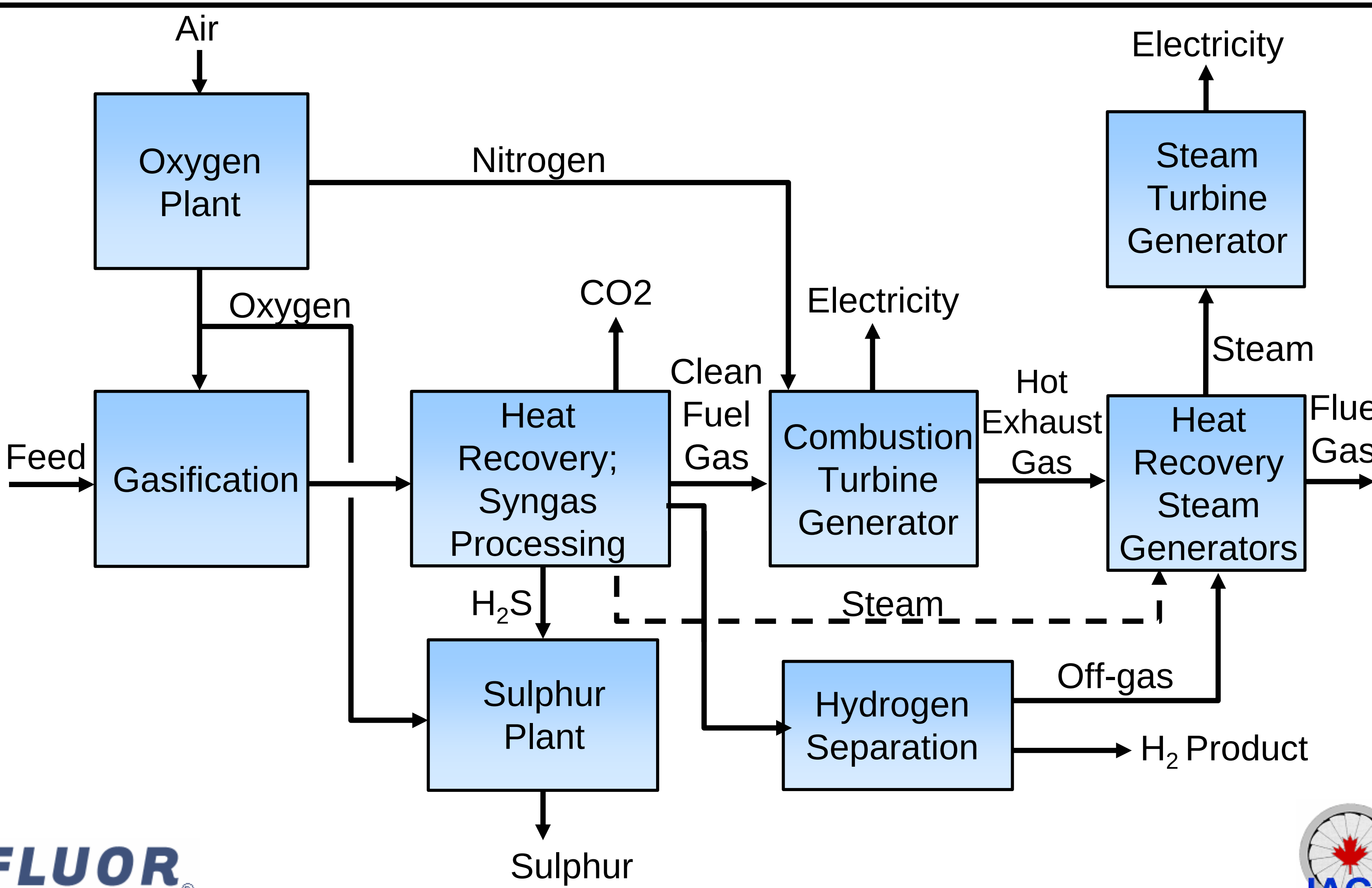
Gasifier Feedstocks

- Vacuum resid
- Visbreaker bottoms
- Solvent Deasphalter Asphaltenes
- Petroleum coke
- Refinery and petrochemical wastes
- Coal / lignite
- Oil emulsion (orimulsion)
- Any carbon-containing material

Gasification Products



IGCC Simplified Block Flow Diagram



Typical Syngas Composition

Syngas Composition, Vol %		
Component	**Heavy Oil Feed**	**Coke Feed**
CO	45.6	47.7
H2	43.3	30.3
CO2	8.2	17.9
H2O	0.3	0.1
CH4	0.4	0.01
Ar	1.0	0.8
N2	0.5	1.3
H2S	0.7	1.8
COS	0.0	0.02

Composition also depends on gasifier licensor

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Emissions

- Excellent Environmental Performance
  - Sulphur recovery to >> 99% depending on recovery process selection.
  - Feedstock metals can be produced as a salable concentrate.
  - Very low emissions from gasifier itself.
  - Downstream emissions dependent upon process for final product.
  - Opportunity for CO_2 recovery.

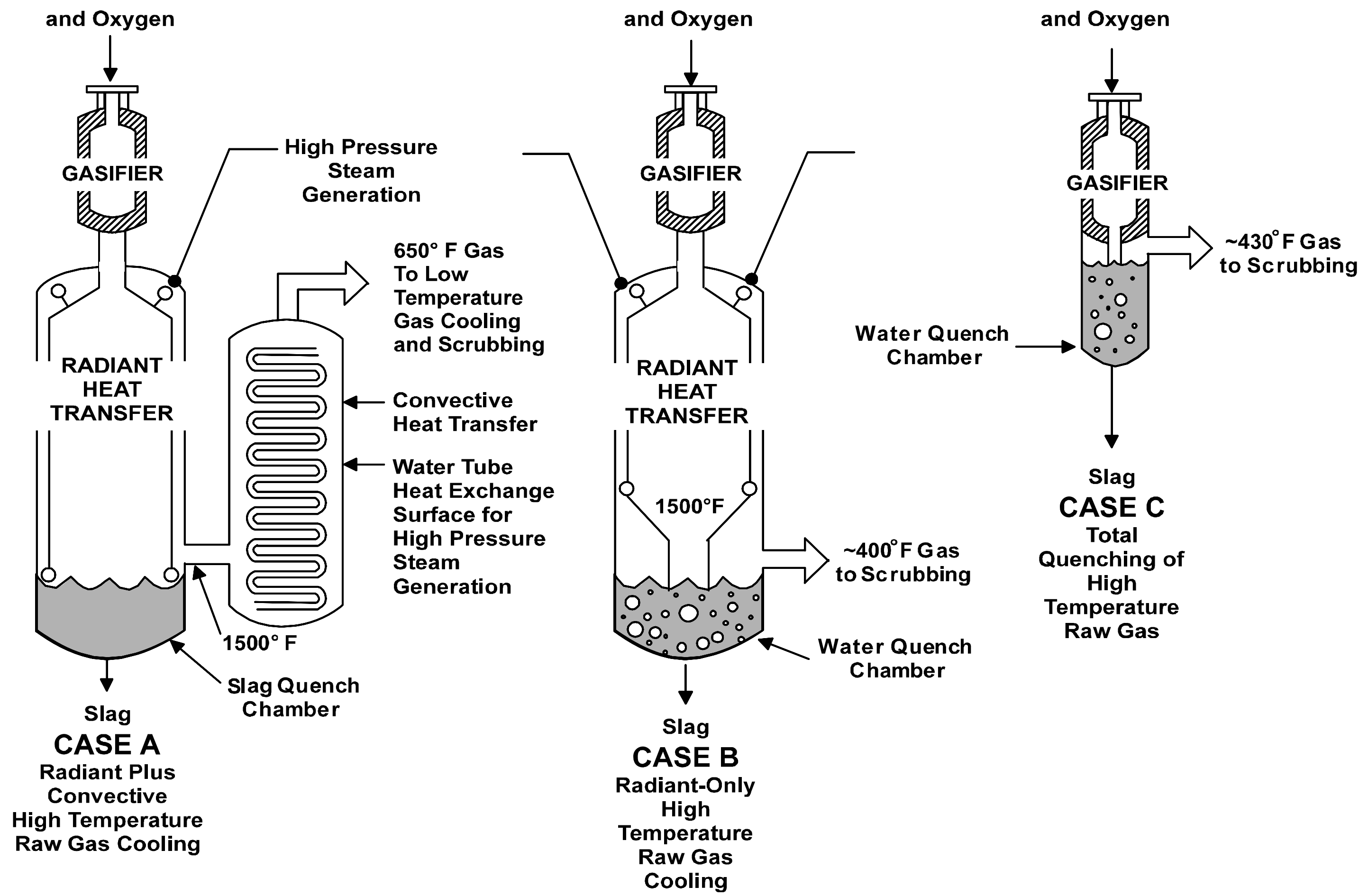
Gasifier Advantage

- Environmentally clean
  - Low SO2, NOx emissions
  - Low solid waste
- Feed flexibility
- Low-cost feedstocks
- Wide selection of technologies / equipment
- Co-product flexibility
- Commercially well-proven

Gasification Licensors

- GE: Well-proven commercially with coal, petroleum coke, and heavy residues.
- Siemens: More experience with coal than coke operation.
- Conoco-Phillips, E-Gas: Most years of commercial experience on coke.
- Shell: Well-proven commercially on heavy resid; less-proven on coal; and demonstration only on petroleum coke.
- Others: Lurgi MPG, Uhde Prenflow, Less experience.

GE Process Waste Heat Recovery Options



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Gasification Technologies

- Synthesis Gas Processing
  - Knowledge and experience with available sulphur species and CO2 removal technologies:
    - Chemical Solvents
    - Physical Solvents
  - Gas turbine and furnace/boiler combustion
  - HCN/COS Hydrolysis
  - Sweet and Sour CO Shift Technologies
    - database of catalyst information from various suppliers
  - Knowledge of complexity of gasification sourced synthesis gas, such as metal carbonyl removal
  - Synthesis via Fischer tropsch, methanation, methanol, ammonia, etc

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Gasification Experience

Client	Project Location	Scope	Feed	Capacity	Comments
Citgo -Lake Charles	Louisiana, USA	FEED	Pet Coke	6,450 TPD, 1,100 MW	**Polygeneration** project to produce steam and hydrogen
TotalFinaElf	Normandy, France	FEED	Visbreaker bottoms	2,000 TPD	**Polygeneration** project. Produced hydrogen and syngas to existing turbines.
Shell Pernis	Rotterdam, Netherlands	E,P,CM	Residue	1,650 TPD, 115 MW	**Gasification/IGCC**. Hydrogen and steam are also produced for refinery.
Chevron / Texaco	Kansas, USA	E,P,CM	Pet Coke	165 TPD, 35 MW	**Gasification/IGCC**. Feed includes 10 tpd of hazardous refinery waste. Produced steam used in refinery.
OPTI Canada	Fort McMurray, Canada	FEED, EP	Asphaltene	3,787 TPD	**Gasification/IGCC**. Produce hydrogen and syngas.

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Gasification Experience

Client	Project Location	Scope	Feed	Capacity	Comments
Wisconsin Electric	Wisconsin, USA	Study	Coal	500 MW	**Gasification/IGCC**. Feasibility study including gasification technology selection.
AGIP	Sannazzaro, Italy	FEED, cost etimates	Residue	1,200 TPD, 275 MW	**Gasification/IGCC** project including gasification technology selection.
SASOL	Secunda, South Africa	E,P,CM	Coal	40,000 TPD	World's largest **gasification** plant. Products include liquid fuels and chemicals.
Motiva	Louisiana, USA	E,P	Residue	4,000 BPD	**Gasification/IGCC**. Feed is bottoms from H-oil unit and other residuals. Hydrogen produced.
ATI	Sardinia, Italy	FEED, consulting	Coal	5,000 TPD, 500 MW	**Gasification/IGCC**.
Sarlux	Sardinia, Italy	FEED, consulting	Residue	4,000 TPD, 500 MW	**Gasification/GT Cogen** project including gasification technology selection. Power,steam and hydrogen produced for upgrader/SAGD.

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Gasification Experience

Client	Project Location	Scope	Feed	Capacity	Comments
Motiva	Delaware, USA	FEED	Coke	2300 TPD, 150MW	**Gasification/IGCC**. Extensive integration with existing refinery systems.
CCPC	Canada	Study	Coal	400 MW	**Gasification/IGCC** project including gasification technology selection.
REPSOL	Spain	Study	Residue		**Gasification/IGCC.**
Chevron Texaco	California, USA	E,P,CM	Coal	20 TPD	**Gasification.** Texaco's pilot plant used for testing process concepts and different feedstocks.
Chevron Texaco	Singapore	FEED	Visbreaker bottoms	800 TPD	**Gasification.** Produce hydrogen and carbon monoxide

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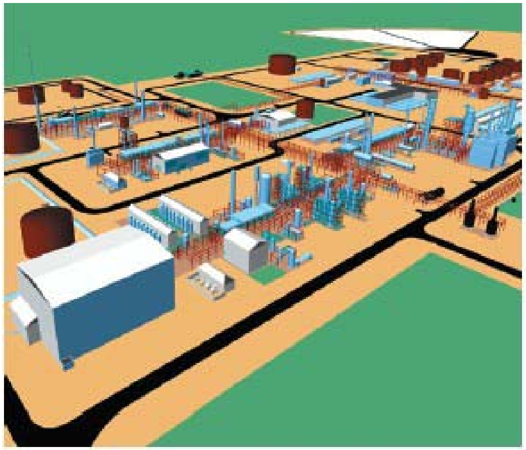
Gasification Experience

Client	Project Location	Scope	Feed	Capacity	Comments
Steelhead Energy	Illinois, USA	FEED	Coal	5,500 TPD, 600 MW	**Gasification/IGCC** project to produce hydrogen and SNG.
Rentech	Illinois, USA	Study	Coal	5,000 TPD	**Gasification**. Conversion of natural gas based 850 t/d ammonia plant. Produce 4,000 bpd diesel and 900 t/d ammonia.
Royster Clark	Illinois, USA	Pre-FEED	Coal		**Gasification.** Conversion of ammonia plant. Hydrogen, carbon dioxide and nitrogen sold over the fence.
Mesaba Energy	Minnesota, USA	Study, FEED	Pet Coke / Coal	530 MW	**Gasification/IGCC.**
CalPine	Texas, USA	Study	Coke	800 MW	**Gasification**. Conversion of NG fired cogen plant.
TCPL	Alberta, CA	Study	Residue		**Gasification**
TCPL	Alberta, CA	Study	Coke		**Gasification**
Confidential	Saskatchewan, CA	Study	Residue		**Gasification**

OPTI/Nexen Long Lake Project



Project: OPTI/Nexen Long Lake Project

Location: Fort McMurray, Alberta

Client: OPTI

Fluor's Scope: FEED & Engineering, Procurement

Fluor was the FEED and detailed engineering contractor for the OPTI/Nexen Long Lake Upgrader which converts 70,000 BPD of SAGD produced bitumen to Premium Synthetic Crude. Fluor assisted OPTI/Nexen in development of the overall upgrader concept, development and optimization of the basic flowsheets, licensor selection, energy optimization, licensor interfacing, RAM, class of facilities definition, etc.

The Asphaltene Gasification Unit is Canada's first gasifier and utilizes the Shell Gasification Process (SGP). The AGU design capacity of 3,787 t/d of asphaltene is achieved with four identical trains. The objective is to maximise the conversion of asphaltenes to syngas while, minimising oxygen/steam consumption and soot generation.

The syngas is treated with Selexol to remove H2S, COS, NH3 and HCN before being further processed to produce high purity hydrogen for the Hydrocracker and CO-rich fuel gas for SAGD. Excess heat from the gasification process is recovered from as high pressure steam. Residual soot from the Gasifier is collected as carbon slurry and extracted from the process as a filter cake.

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Greenhouse Gas – The Regulatory Situation

- Oil Sands to generate 25% Canadian CO_2 by 2020
- Kyoto – Canada opted in
- Alberta's Climate Change Plan
  - Applies to 100+ facilities > 100,000 TPY of CO_2 (equilavent)
  - Reduce by 12% over 5 years
- New Canadian Federal Announcement
  - Targets oils sands and coal fired power plants
  - 20% reduction by 2020, 60-70% by 2050
  - 18% reduction per unit production by 2010
  - Then 2% per year to 2020

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Questions?

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