The Push to Coal Gasification

in Alberta

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Introduction

Gasification is an ancient art whereby a solid carbon-based feedstock is converted into a gas product with usable heat value. These feedstocks, being coal, biomass, pet-coke, residual oils, or natural gas, go through partial oxidation to produce a synthesis gas (syngas) largely composed of hydrogen and carbon monoxide.

This paper will look specifically at coal gasification as this has the largest impact on Canada and Alberta, specifically in developing a higher value and more environmentally acceptable usage of coal when compared to straight combustion. Modern coal gasification also introduces a cost-effective substitute to natural gas in the form of syngas and hydrogen that can replace natural gas usage for larger natural gas users (such as the oil sands) allowing the natural gas to be freed up for other commercial markets. Finally, the hydro-gasification process produces a relatively pure and easily captured CO₂ stream that normal coal combustion does not allow (or is highly uneconomical). In Alberta this carbon dioxide stream is an additional product line for the coal gasifier, who can sell the product to the oil industry for enhanced oil recovery.

Why Coal Gasification Now?

Recent interest and investment in coal gasification is primarily driven by economic factors relating to the demand and price of natural gas. In North America, natural gas demand has exceeded supply in almost all sectors leading to sustained high prices for natural gas. Fertilizer, chemical production, and electricity generation (in the United States particularly) have been largely dependent on natural gas feedstocks. Current
natural gas prices have greatly constrained North American fertilizer production, driven up chemical costs and pushed natural gas electrical generation plants, on average, to less than 35% capacity and nearly an eighth of these plants into financial distress. Coal gasification is seen as a viable substitute for natural gas, as the hydrogen and carbon monoxide syngas can not only replace the natural gas feedstock, but it can also be consumed in most of the existing infrastructure (plants, refineries) at minimal conversion costs.

Coal, unlike petroleum, is more uniformly distributed globally. For developing nations such as China and India, this makes coal a valuable domestic hydrocarbon resource to drive domestic growth. Approximately 35 MM tonnes/year of coal is gasified or less than 2% of annual coal consumption. About half of this production is done in South Africa to produce synfuels and the remainder is for consumed in ammonia production. China and India are increasing their use of coal gasification for town-gas (China), chemical and fertilizer production, and have Integrated Gasification Combined Cycle electric plants currently under construction. South Africa, in a drive to establish oil-supply independence, has developed Coal-to-Liquids and Gas-to Liquids technologies based on the Fisher-Tropsch technologies developed in the 1920s. Today, with its abundant coal reserves, more than 40% of South Africa’s liquid fuels are produced through gasification and South Africa is an active exporter of both Coal/Gas-to-Liquid technologies and products.
History

Coal had been widely used for heat and cooking, originally as a substitute for wood. By the late 18th century, coal gasification was developed, mostly in England, to provide a cleaner fuel that could be used for cooking and lighting. The production of ‘town-gas’ was relatively expensive, had low heating value, and encountered significant transportation and distribution obstacles. While the town-gas was widely used up to the 1940s, it was largely replaced in the 1950’s by heating oil and the cheaper natural gas with its significantly higher heat value. It is important to note that town-gas introduced domestic gas usage and the general acceptance of household delivery of highly volatile gas products.

Coal gasification has always been an expensive alternative to natural gas and the interest in the development of the technologies has been concentrated during periods of high natural gas prices or petroleum shortages. Wartime Germany used coal gasification to produce synthetic fuels. South Africa’s SASOL, the world’s largest coal gasifier, produces a variety of synthetic fuels through technologies developed to overcome petroleum embargo shortages. The first oil shock in the 1970s saw great investment in order to produce a substitute natural gas product in the United States. While not commercially successful, the process introduced the requirement of high pressure to optimize gasification and this has driven much of today’s technological development.

Today, in addition to the economic drives, coal gasification presents environmental and energy-base transformation opportunities. Integrated Gasification Combined Cycle
(IGCC) electrical power plants (originally funded by the US Department of Energy) are commercially operating in three American sites with several more under development. IGCC generation is only marginally more efficient when compared to straight coal-fired electrical generation based on Net Coal-to-Power efficiency (42% efficiency for IGCC, 41% for current coal-fired generation), but significant gasification benefits are seen in CO₂ capture and lower NOₓ and SO₂ emissions. Compared to pulverized coal plants, coal gasification facilities capture CO₂ at approximately 43% of the cost, mercury removal is about 10% of the cost, and SO₂ and NOₓ emissions are below current pulverized coal permit limits. Coal-gasification further allows an effective means of producing a clean pure stream of hydrogen in sufficient supply to begin to transfer the world’s dependence on carbon-based fuels to hydrogen.

**Gasification Process**

**Chemical reactions and fuels**

Carbon gasification combines a carbon feedstock, high temperature and pressure in a controlled limited-oxygen environment. Here an exothermic reaction occurs to produce a syngas that is mainly composed of carbon monoxide and hydrogen. The important reactions are as follows:

\[
\begin{align*}
C + H_2O & \leftrightarrow H_2 + CO \\
C + \frac{1}{2} O_2 & \leftrightarrow CO \\
& \quad \text{(plus Some CO₂)}
\end{align*}
\]

---

¹ IGCC efficiency runs at about 54%; however, approximately 12% of the coal energy is consumed in running the gasification process.
At this point the syngas is scrubbed to remove various particles and trace metals that are inherent in the feedstock. Following the cleaning, the syngas can be marketed as a viable commercial gas or using carbon monoxide and hydrogen as basic building blocks for chemical or fertilizer production. Alternatively, the syngas can be further refined in a steam shift reactor to convert the remaining carbon monoxide into hydrogen and carbon dioxide:

\[
CO + H_2O \leftrightarrow CO_2 + H_2
\]

Final cleaning is required to remove hydrogen sulfides and to separate the carbon dioxide and hydrogen. All three products have commercial applications.

**Sherritt’s Dodds-Roundhill Gasification Plant**

In January 2007, Sherritt International announced that it would build Canada’s first coal-fed gasification plant near Camrose, Alberta. The project is designed to be a three-phased facility that will add additional gasifiers with each phase and bring on additional products from the gasification.

Sherritt International, who controls substantial coal resources in Western Canada, has determined that electrical generation is not (at this time) viable in Alberta with current coal gasification technologies. This is largely due to the discontinuity of pricing between coal-ore mining and delivery to the final pricing of electricity from coal-fired electrical generation. Current coal-fire electrical generation is based on efficient earth moving equipment to provide the coal feedstock at a ‘relatively’ fixed-cost per ton. Sherritt estimates that their syngas would have a cost of between $3-5/GJ in today’s market,
while mined coal-ore has an approximate value of $0.50/GJ. With electricity at a market value of $13-14/GJ and no present way to value the CO₂ emissions from coal-fired generation, Sherritt views power generation from syngas as non-competitive. Unless power generation is fully integrated (from mining to generation) in a co-production facility, electric production is not a viable use of Sherritt’s syngas resources. Rather, Sherritt is looking at coal as a carbon-ore that contains valuable products including carbon, hydrogen, oxygen, nitrogen, trace materials and ash. For Sherritt, it is a question of why burn an unrefined product when, through gasification, refined components can be extracted for specified use.

The first phase of the Dobbs-Roundhill facility will focus on hydrogen production. That facility, including the mine, will cost $1.5-1.6B and is scheduled to go into production in 2012. According to Sherritt’s estimation, natural gas prices in excess of $7/GJ will make the project commercially viable.

The coal resource for the initial mine has approximately 320 million tonnes of sub-bituminous coal in relatively shallow seams. This reserve, which will be mined in an open pit operation, is estimated to cover the supply requirements of the facility for the first two phases of the project and have a 40-year lifespan. An additional 280M tonnes of reserves are available in the region to supply resources for future phases of the project. The mine will supply 7,000-8,000 tonnes/day to each gasification units.
Phase 1 will operate one Future Energy (Siemens) entrained flow gasifier that will operate at approximately 1400º C. This first gasification unit will produce 320 million scf/day of syngas that will be processed to 270 million scf/day of pipeline-grade hydrogen. The facility will also produce 12,500 tonnes/day of CO₂, and 30-150 tonnes/day of sulphur.

Sherritt currently holds commitments (mainly in the Fort Saskatchewan region) to purchase the hydrogen product and holds further commitments on its CO₂ production for enhanced oil recovery (EOR) within the Camrose region. In fact, Sherritt estimates that current regional CO₂ demand for EOR exceeds its supply by more than 2,500 tonnes/day (within a 60 km radius). An important element in the site selection of Dobbs-Roundhill, was to be located within reasonable proximity to oil basins with appropriate geological formations to accept and retain CO₂ sequestration.

Unique to the gasification of coal in entrained-flow gasifiers, the residual slag is a fine grain, inert glassy product that does not leach. The sudden drop in temperature during the water quenching of the molten slag, traps trace metals (nickel, chrome, zinc, lead, arsenic) within the slag granules. The benefit is that this slag, being inert, can be sent directly for backfilling at the mine or be used as a granular product in applications including road construction, concrete, and roofing material.
Northern Lights Redwater Upgrader

The Northern Lights $3.6B upgrader is targeted to come into production in 2010. The facility will be a phased project with the initial phase set to produce 50,000 bbl/day of synthetic crude oil. Northern Lights is a partnership with Calgary based Syneco (60%) and China’s largest oil refiner, Sinopec (40%).

Included in the project will be an asphaltene gasifier that will take a low value waste product, asphaltene, from the facility’s internal bitumen upgrading and produce syngas, hydrogen, and carbon dioxide. The majority of the gasified product will be used within the upgrader as a natural gas replacement. Gasification is expected to supply most of the upgrader’s fuel and hydrogen needs, which in turn will increase economic efficiency for the upgrader, and reduce waste products.

Northern Lights, like Sherritt, has decided not to invest in electrical generation from its gasification unit (citing a “reliable” local electrical supply), but rather further process through to hydrogen for use in the upgrader’s hydrocracker and sell excess product in the local market. Northern Lights has also entered into a memorandum of understanding with Agrium Inc. to supply excess hydrogen, carbon dioxide and sulphur for Agrium’s use at its neighbouring fertilizer operation. Infrastructure investments will be required, mainly to connect the two facilities; however, Agrium Inc. will be able to switch its feedstock to long-term hydrogen streams and away from the volatile natural gas market.

2 Sinopec currently runs four gasification units within its China operations.
Northern Lights will use GE Energy’s entrained-flow gasifier that will produce a molten slag and will be water quenched exiting the reactor. The GE gasifier has refractory brick lining that will require semi-annual maintenance, but is required to deal with particulate build up in the gasifier from the mined feedstock (see SAGD below). Pet-coke gasification presents some challenging additional problems due to the product’s high molten temperature and its low silica content. To overcome these issues, lime must be added to the feedstock to lower the molten temperature in the gasifier from about 2,000°C to 1,400°C. Silica and calcium will also need to be added to glassify the slag product during water quenching to render it inert. Alternatively, the pet-coke could be mixed with an 80% coal feedstock to produce the same results. (This has more significant impact for upgrader gasification units that are located in the Fort McMurray area with readily accessible coal reserves or for the Sherritt project as an additional feedstock).

**Other Gasification Proposals**

Several other gasification projects in Alberta have been announced, all of which are similar to the Northern Lights pet-coke gasification process. Recent interest in switching to gasification of pet-coke in the oil upgrading remains to have strong economic drivers from sustained high natural gas prices, but increasingly this switch is being propelled by a excess supply of pet-coke wastes within the heavy oil and bitumen upgrading industry. Alberta is currently sitting on substantial inventories of pet-coke wastes which will only grow with further oil sands expansion. However, realization of most of these pet-coke gasification projects remains dependent on relative natural gas pricing.
**OPTI Canada/Nexen Inc. Long Lake Project**

OPTI will use an ashphaltene feedstock to produce hydrogen and fuel gas (syngas) for steam generation. The steam generation will be used in the facilities Steam Assisted Gravity Drainage (SAGD) operation. Unlike the Northern Lights relatively non-selective mining operation, the SAGD process recovers a product that does not have the same concentration of ultra fine particulates (i.e. vanadium, nickel) that are present in the mined asphaltene product. When gasified, these particulates build up in the gasifier and therefore require special reactor linings and greater reactor maintenance. Ultra-fine particulates are virtually non-existent in the SAGD product, making the SAGD asphaltene as a much superior feedstock for gasification.

**Suncor Energy Inc., Voyageur Two Fort McMurray**

Suncor will include a gasification unit for hydrogen and fuel gas for internal consumption in its third upgrader as a part of the Voyageur Two expansion that is projected for completion in 2012.

**North West Upgrading, Redwater**

A $2.4 Billion upgrader will include a pet-coke gasification unit. The proposed facility will match the scale of the Northern Lights project and also come on-line in 2010.

**Peace River Oil Inc., Bluesky Project, McLennan**

Bluesky is a $2.5 Billion upgrader for heavy crude oil scheduled for completion in 2011 and will be the first heavy oil upgrader in the Peace River area. The gasification unit is
expected to make Bluesky virtually energy independent with hydrogen, steam and power being produced through the gasification of asphaltenes.

**Hurdles to Overcome**

**Public Perception**

Gasification in itself will meet with minimal public resistance as it presents a ‘greener’ technology and better utilization of current resources. The technology is widely used and proven internationally as viable and environmental. Resistance to the projects will be encountered in four basic areas: CO₂ sequestration, Open Pit Coal Mining, Water Usage and Transport, and Infrastructure Development.

**CO₂ Sequestration**

Much of the CO₂ sequestration for proposed projects will be used in enhanced oil recovery in depleted oil fields. While the technology is developing and similar technologies have been used with other gas products, the long-term impacts of permanent CO₂ storage in depleted wells is not yet fully understood. Public resistance will likely be expected to both the transportation and the storage of CO₂ from persons within the affected areas.

**Open Pit Mines (coal)**

For Sherritt, the mine will present a significant challenge from the local public. While Sherritt is proposing a series of parallel open pits that will be refilled as the coal is mined, their proposed site is in a prime agricultural region with well-established productive
agricultural farms. Currently, Sherritt estimates a 6-year turnaround for agricultural production and ‘certified’ reclaimed within 9 years. However, even given these timelines, public displacement and the regional impact from the mine-site itself will have substantial socio-economic impacts.

**Water Usage**

Water is required for the gasification process, cooling, feedstock preparation and other service needs in each of the proposed facilities. Sherritt estimates that the Dobbs-Roundhill project alone will require between 2.4 and 9.5 million m$^3$ per year. As this supply cannot be met locally, this will require the construction of a water pipeline and intake facilities from the North Saskatchewan River. While water allocation is still available within the North Saskatchewan River Basin, water usage issues, particularly concerning hydrocarbon production, remains a contentious public issue.

**Infrastructure Development**

Fort Saskatchewan-Sturgeon County is home to a number of large petroleum and chemical facilities that have had positive and negative socio-economic impacts. While new facilities will likely proceed after appropriate review, the continued concentration of the facilities in the area is likely to be met with greater public resistance. Furthermore, connecting infrastructure (pipelines, roads, transmission lines) will have to be expanded. Financing of the development of this infrastructure is a growing problem as industry will be looking at government to assist not only in the development of transportation networks
but also in a pipeline backbone infrastructure to connect Fort McMurray with Edmonton (Sturgeon County) for bitumen, hydrogen and CO₂.

**Future of Gasification**

While the current push for gasification in Alberta is centred on natural gas replacement and waste management in the petroleum industry, gasification holds a variety of opportunities internationally through the development of Energyplexes. Energyplexes are integrated energy systems that can supply long-term energy demands. Within these facilities, primarily through gasification, a variety of energy would be co-produced (hydrogen, liquid fuels, electricity). Yamashita and Barreto, in their paper “Energyplexes for the 21st Century” emphasize coal gasification as an ideal resource based on the worldwide abundance of coal, the variety of other carbon feedstocks that can be combined with coal in gasification (pet-coke, biomass, oils), and the various energy products that can be produced in gasification. They conclude that co-generation may improve the economics of the production system and allow the exploitation of one energy product over another as product demand shifts.

Gasification may also increase efficient resource use when produced in energyplexes. Sasol gas-to-liquids technologies (gasification) are used in Mozambique, Qatar and Nigeria to transform excess natural gas supply into more transportable Fisher-Tropsch liquids. Sherritt is looking in this same direction with the focus of the Dodds-Roundhill Phase II and Phase III expansion to focus on chemicals and synthetic liquids, respectively.
Michael C. Moore in his paper “The Missing Link: An Evaluation of the Proposed
Northern Lights Transmission Project” emphasizes that gasification and cogeneration of
residual pet-coke in the Fort McMurray area are key in the construction of the proposed
TransCanada Corporation’s direct current transmission line from Fort McMurray to the
Pacific Northwest. He concludes that the transmission line would have a net benefit to the
province, stimulate gasification and technologies in Alberta, and address environmental
issues surrounding the disposal of pet-coke.

Gasification, like many things in the world, has ‘come around again’ since its early
beginning; however, this time it holds a number of significant keys to answer current and
future energy demands.
Source Materials


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