Mitretek Technical Report

Potential Application of Coal-Derived Fuel Gases for the Glass Industry: A Scoping Analysis

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Disclaimer

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Introduction

In the glass industry, high temperature, oxygen-blown, natural gas fired furnaces are operated continuously at temperatures around 1650 degrees centigrade for up to 15 years with little change in energy input. For example, a color TV furnace and a large float furnace would typically consume approximately 150 to 200 million Btu per hour. To insure that adequate supplies of natural gas are constantly available to keep the bath above the critical melt temperature, the glass industry usually has to pay high premiums to gas suppliers to provide reliable uninterrupted supply. Compounding this, the cost of natural gas has doubled in the past two years and, although some manufacturers have escalation clauses that allow part of this cost to be passed on to customers, cost increases of the magnitude resulting from current high natural gas prices are too large to be passed on. This has resulted in many glass manufacturing plants in the U.S. being closed down costing America good paying jobs.

Driving high natural gas prices is the balance between supply and demand. There is currently great concern regarding the future supply of natural gas in the U.S. Domestic production is in decline and, it is generally agreed, that to provide adequate supply new sources of gas from frontier regions and imports of LNG will be necessary, Still natural gas remains the primary source of combustion energy for not only the glass industry but also for other primary process industries like steel, aluminum, and fertilizer manufacture.

Domestic coal can be converted into medium Btu fuel gas or into substitute natural gas (SNG) via gasification technology. Using coal to provide fuel for the glass and other manufacturing industries would contribute to a secure domestic supply of gas and relieve the pressures on the tight gas market. Technologies are currently available to convert coal into fuel gas and electric power in an environmentally responsible manner. The economics of this conversion depend on many factors including the configuration, the technology used, the price of coal, and the market value of the products.

The objective of this study is to explore the economic viability of producing coal-derived fuel gases for use in the glass manufacturing industry as an alternative to natural gas. In this study small size gasification systems that suffer adversely from economics of scale were not considered. Instead, full-scale commercial gasification systems were analyzed that could produce enough fuel gas and electric power for several manufacturing plants. The possibility exists to gather a number of large manufacturers in a geographically centralized location in an Industrial Gasification Island (IGI) complex so that a central coal gasification plant could provide fuel and power to all of these industries.

Overview of Cases Analyzed

Table 1 describes the five (5) cases analyzed in this report. In Case 1, a single GE/Texaco quench type coal gasification system is used to produce synthesis or medium Btu fuel gas. No spare gasifier is used in this case and the availability is estimated to be 85 percent. That is the fuel gas is produced for 365*0.85 or 310 days per year. For the other 55 days the gasifier is assumed to be undergoing maintenance and is unavailable. Because the glass industry emphasized the requirement for reliability of supply of gas, Case 1(S) was analyzed. In this case a hot spare GE/Texaco gasifier was included so that the overall availability of medium Btu fuel gas was increased to 98 percent. In Case 2, the single GE/Texaco process was used to produce synthesis gas that was then sent to a methanation reactor to produce SNG. Because a single gasifier was used the availability was assumed to be 85 percent as in Case 1.

The glass industry uses oxygen-blown furnaces to obtain the high temperatures necessary to melt the glass. They buy oxygen from industrial gas suppliers for a high price. Because coal gasification uses oxygen to feed to the gasifier, at this scale it would be possible to oversize the air separation unit and provide oxygen as well as fuel gas to the glass industry. In Case 3, both medium Btu fuel gas and oxygen are produced by using GE/Texaco gasification with one hot spare. Again because of the hot spare it is assumed that 98 percent availability can be obtained.

In Case 4, a larger gasification plant is analyzed. In this case two trains of ConocoPhillips E Gas gasifiers are used to produce medium Btu fuel gas, oxygen, and electric power. The two-stage E-gas process has higher cold gas efficiency than GE/Texaco. Using two trains makes it possible to obtain 98 percent availability for the fuel gas and oxygen, and 75 percent availability for the electric power.

Coal Analysis

Table 2 shows an analysis of the coal used in this study. This coal, used in prior Mitretek studies and in the systems analysis studies of Parsons (1), is an Illinois # 6 bituminous coal with a higher heating value of 11,666 Btu per pound on an as-received basis.

Details of Cases Analyzed

Case 1: Syngas Production with Single GE/Texaco Gasification

Figure 1 shows a schematic of the Case 1 plant configuration. In this case a single GE/Texaco quench gasifier is used to produce the synthesis or medium Btu fuel gas. The coal (3030 tons per day) is slurried with water and the slurry is pumped to the gasifier where it is gasified with oxygen. The raw gas exiting the gasifier is water quenched and the quenched output is sent to carbonyl sulfide hydrolysis and then to acid gas removal. The acid gas is sent to a Claus/SCOT combination to recover sulfur. The clean synthesis gas is then split into three streams. One stream is sent to a superheater where high pressure steam is raised for a steam turbine to provide electric power for the plant power requirements, another small stream is used for plant fuel, and the third stream is the product gas for sales. After satisfying plant power needs, 8.8 MW of power was sent for sales. The quantity of synthesis gas produced by this plant was 1,929 MMBtu per hour.

Table 1. Cases Analyzed

Case 1	Single GE/Texaco Quench Gasification	Syngas	85% Availability
Case 1(S):	GE/Texaco Quench Gasification (Hot Spare)	Syngas	98% Availability
Case 2	Single GE/Texaco Quench Gasification	SNG	85% Availability
Case 3	GE/Texaco Quench Gasification (Hot Spare)	Syngas + Oxygen	98% Availability
Case 4	E-Gas Gasification Two Trains	Syngas +Oxygen+ Power	75% Availability for Power/98% for Syngas +O_2

Table 2. Coal Analysis

- Illinois #6 Old Ben #26 Mine
- Proximate as-received (wt %)
  - Moisture 11.12
  - Ash 9.7
  - Volatile matter 34.99
  - Fixed carbon 44.19
  - HHV Btu/# 11,666

- Ultimate as-received (wt %)
  - Moisture 11.12
  - Carbon 63.75
  - Hydrogen 4.5
  - Nitrogen 1.25
  - Chlorine 0.29
  - Sulfur 2.51
  - Ash 9.7
  - Oxygen (bd) 6.88

The overall plant efficiency, defined as the thermal output of syngas and power divided by the thermal coal input, is calculated to be 66.5 percent on an HHV basis. The plant availability with only one gasifier is assumed to be 85 percent. That is the synthesis gas is produced for 365*0.85 or 310 days per year. The numbered streams in Figure 1 show selected material flows for this configuration. Table 3 details these flows.

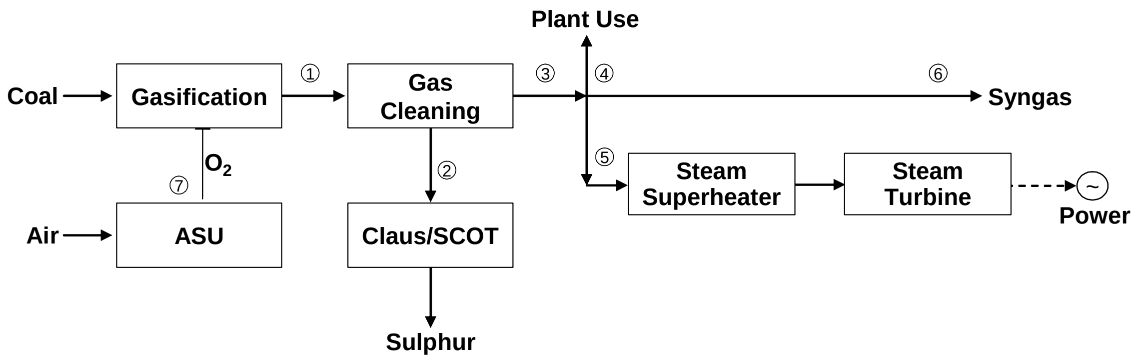

Figure 1. Case 1: Syngas Production with a Single GE/Texaco Gasifier

Table 4 summarizes the capital and operating costs for this Case 1 configuration. Total capital including non-depreciable capital is estimated to be \$291 MM (2004 dollar basis). Coal was assumed to be available at \$29 per ton so that coal feed cost for the plant was \$27 MM per annum. Operating and maintenance cost, less coal cost, was estimated to be \$17 MM per annum. Net total operating cost was \$43 MM per annum. To calculate the required selling price (RSP) of the synthesis gas, the financial parameters used are shown in Table 5. The debt:equity ratio used indicates that these projects are considered to be intermediate between high and low risk projects. Using these parameters the RSP of the synthesis gas is calculated to be \$5.32 per MMBtu.

Case 1(S): Syngas Production using GE/Texaco Gasification with Hot Spare

Figure 2 shows a schematic of the Case 1(S) plant configuration. This case is similar to Case 1 except that there is a hot spare GE/Texaco quench gasifier on stand by. The hot spare is assumed to increase the availability from 85 percent in Case 1 to 98 percent in this case. This increase in availability is probably necessary to satisfy the glass industry requirement of a reliable gas supply for their glass furnaces. As in the prior case, the coal (3030 tons per day) is slurried with water and the slurry is pumped to the gasifier where it is gasified with oxygen. The raw gas exiting the gasifier is water quenched and the quenched output is sent to carbonyl sulfide hydrolysis and then to acid gas removal. The acid gas is sent to a Claus/SCOT combination to recover sulfur. The clean synthesis gas is then split into three streams. One stream is sent to a superheater where high pressure steam is raised for a steam turbine to provide electric power for the plant power requirements, the second is plant fuel, and the third is the product gas. After satisfying plant power needs, 8.8 MW of power was sent for sales. The quantity of synthesis gas produced by this plant was the same as Case 1 at 1,929 MMBtu per hour. The overall plant efficiency was therefore 66.5 percent on an HHV basis. The stream flows are identical to Case 1.

Table 3. Case 1: Syngas Production, Single GE/Texaco Gasifier

Selected Flows, Pound Moles/Hour										
	1				2	3	4	5	6	7
	Gasifier Output	Quench Water	Quenched Output	Cooled Gas	Sour Gas	Clean Gas	Plant Gas	Superheater Gas	Product Syngas	ASU Oxygen
CH4	3		3	3	0	3	0	0	2	
H20	4,500	28,000	30,950	0	0	0	0	0	0	
H2	7,854		7,854	7,854	39	7,815	63	977	6,775	
C0	10,392		10,392	10,392	10	10,381	84	1,298	8,999	
C02	2,889		2,889	2,889	2,860	29	0	4	25	
N2	157		157	157	0	157	1	20	136	
H2S	198		198	198	198	0	0	0	0	
NH3	57		0		0	0	0	0	0	
O2										6,618
Total	26,048	28,000	52,441	21,492	3,107	18,384	149	2,298	15,938	6,618
T, Deg F	2500	250	432	432		85	85	85	85	59
P, atm	41.8		40.2	38.2	1	36.3	36.3	35	35	44

Table 4. Case 1: Single GE/Texaco Quench Syngas Production

Construction Cost Estimate

	$MM
Coal Handling	13
Gasification	51
Gas Cleaning	31
Oxygen Plant	51
Heat Rec/Power Gen	42
Balance of Plant	33
	221
Home Office/Fee	23
Contingency (15 percent)	36
	280
Non-depreciable Capital	11
Total Capital	291

Operating Cost

	$MM/Yr
Coal ($29/Ton)	27
Consumables	1
Labor/OH	4
Local Taxes/Insurance	5
Maintenance/Other	7
	44
By-product Credit	1
Net Operating Cost	43

Coal Input	3030 TPD (AR)
Availability	85%
Syngas Output	1929 MMBTU/Hr
Net Power Output	8.8 MW
Overall Efficiency	66.5 (HHV)

RSP Syngas = $5.32/MMBTU
Power Value $35.6/MWH

Table 5. Financial Assumptions

- 25 year plant life
- 67/33% debt/equity financing
- 15% return on equity
- 8% interest, 16 year term
- 3% inflation
- 16 year DDB depreciation
- 38% combined Federal and State tax rate
- 3 year construction, 50% output in start-up year

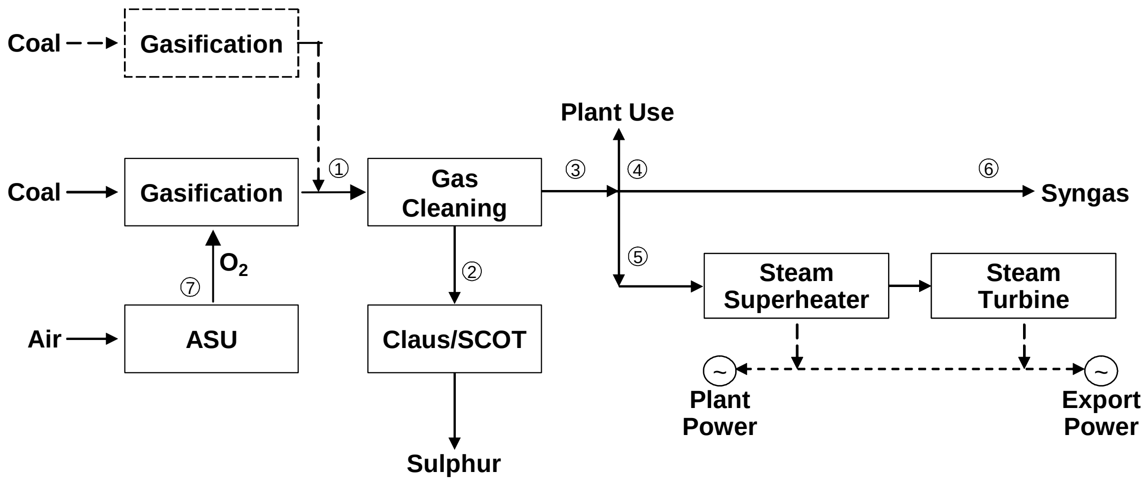

Figure 2. Case 1(S): Syngas Production with a Single GE/Texaco Gasifier and Spare

Table 6 summarizes the capital and operating costs for this Case 1(S) configuration. Total capital including non-depreciable capital is estimated to be $359 MM (2004 dollar basis). Coal feed cost for the plant was $31 MM per annum. This is greater than for Case 1 because the availability of this plant has increased to 98 percent. Operating and maintenance cost, less coal cost, was estimated to be $20 MM per annum. Net total operating cost was $50 MM per annum. Using the financial parameters in Table 5, the RSP of the synthesis gas is calculated to be $5.53 per MMBtu. These financial assumptions were used to be consistent with prior Mitretek analyses of coal conversion technologies.

Case 2: Production of SNG using Single GE/Texaco Gasification

Figure 3 shows a schematic of the Case 2 plant configuration. In this case, SNG is produced from the synthesis gas by methanation. The quenched synthesis gas from the oxygen-blown GE/Texaco gasifier is sent to a raw water gas shift reactor to adjust the hydrogen to carbon monoxide ratio to be compatible with methanation. The shifted gas is then sent to acid gas removal. The acid gas is sent to a Claus/SCOT combination to recover sulfur. The clean synthesis gas is then sent to a three stage methanation reactor system where the synthesis gas is converted into methane or SNG. A small side stream of the synthesis gas before methanation is used as plant fuel. Methanation is a very exothermic reaction and the exothermic heat is used to generate high pressure steam. This steam is used in a steam turbine to generate electric power for plant power requirements. After satisfying plant power needs, 5.3 MW of power was sent for sales. The quantity of SNG produced by this plant was 1,739 MMBtu per hour, equivalent to about 42 MMSCFD of SNG. The overall plant efficiency was 59.6 percent on an HHV basis. Plant availability was assumed to be 85 percent because there is no spare gasifier in this configuration. The numbered streams in Figure 3 show selected material flows for configuration 2. Table 7 details these flows.

Table 6. Case 1S: GE/Texaco Quench (Hot Spare) Syngas Production

Construction Cost Estimate

	$MM
Coal Handling	13
Gasification	101
Gas Cleaning	31
Oxygen Plant	51
Heat Rec/Power Gen	42
Balance of Plant	35
	273
Home Office/Fee	28
Contingency (15 percent)	45
	346
Non-depreciable Capital	13
Total Capital	359

Operating Cost

	$MM/Yr
Coal ($29/Ton)	31
Consumables	1
Labor/OH	4
Local Taxes/Insurance	7
Maintenance/Other	8
	51
By-product Credit	1
Net Operating Cost	50

Coal Input	3030 TPD (AR)
Availability	98%
Syngas Output	1929 MMBTU/Hr
Net Power Output	8.8 MW
Overall Efficiency	66.5 (HHV)

RSP Syngas = $5.53MMBTU
Power Value $35.6/MWH

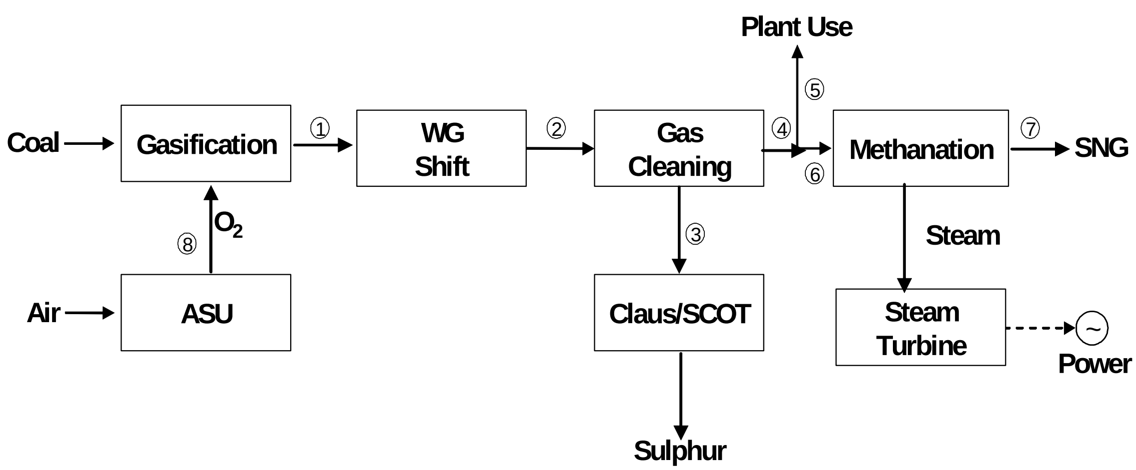

Figure 3. Case 2: SNG Production with a Single GE/Texaco Gasifier

Table 7. Case 2: SNG Production Single GE/Texaco Gasifier

Selected Flows, Pound Moles/Hour										
	1			2	3	4	5	6	7	8
	Gasifier Output	Quench Water	Quenched Output	Shifted Gas	Sour Gas	Clean Gas	Plant Fuel	Methanator Feed	Product SNG	ASU Oxygen
CH4	3		3	3	0	3	0	3	4,365	
H20	4,500	28,000	30,950	0	0	0	0	0	42	
H2	7,854		7,854	13,684	68	13,616	110	13,506	574	
C0	10,392		10,392	4,561	5	4,557	37	4,520	4	
C02	2,889		2,889	8,719	8,632	87	1	86	241	
N2	157		157	157	0	157	1	155	155	
H2S	198		198	198	198	0	0	0	0	
NH3	57		57	0	0	0	0	0	0	
O2										6,618
Total	26,048	28,000	52,498	27,322	8,902	18,419	149	18,271	5,381	6,618
T, Deg F	2500	250	432	666	151	85	85	483	100	59
P, atm	41.8		40.2	38.2	36.3	36.3	35	34	34	44

Table 8 summarizes the capital and operating costs for this Case 2 configuration. Total capital including non-depreciable capital is estimated to be $344 MM. Coal feed cost for the plant was $27 MM per annum. Operating and maintenance cost, less coal cost, was estimated to be $20 MM per annum. Net total operating cost was $46 MM per annum. Using the financial parameters in Table 5 the RSP of the SNG is calculated to be $6.75 per MMBtu on an HHV basis. Because the synthesis gas must undergo methanation to produce SNG, the RSP of SNG is higher than for the production of synthesis gas by approximately $1.40/MMBtu.

Table 8. Case 2: Single GE/Texaco Quench SNG Production

Construction Cost Estimate	$MM	Operating Cost	$MM/Yr
Coal Handling	13	Coal ($29/Ton)	27
Gasification	51	Consumables	2
Shift	15	Labor/OH	5
Gas Cleaning	28	Local Taxes/Insurance	6
Oxygen Plant	51	Maintenance/Other	7
Methanation	38		47
Heat Rec/Power Gen	27	By-product Credit	1
Balance of Plant	38	Net Operating Cost	46
	261		
Home Office/Fee	27		
Contingency	43		
	331		
Non-depreciable Capital	13	RSP SNG = $6.75/MMBTU	
Total Capital	344	Power Value $35.6/MWH	

Coal Input	3030 TPD (AR)
Availability	85%
SNG Output	1739 MMBTU/Hr
Net Power Output	5.3 MW
Overall Efficiency	59.6% (HHV)

Case 3: Production of SNG and Oxygen using GE/Texaco Gasification with Hot Spare

Figure 4 shows a schematic of the Case 3 plant configuration. This case is similar to Case 1(S) in that there is a hot spare GE/Texaco quench gasifier on stand by. The hot spare is assumed to increase the availability from 85 percent to 98 percent in this case. However, in this case, in addition to producing synthesis gas, oxygen is produced for sales to the glass industry for oxyfiring in the furnaces. This necessitates the inclusion of an additional air separation unit (ASU) in the design and additional plant electric power is required to run the ASU air and oxygen compressors to produce this additional oxygen.

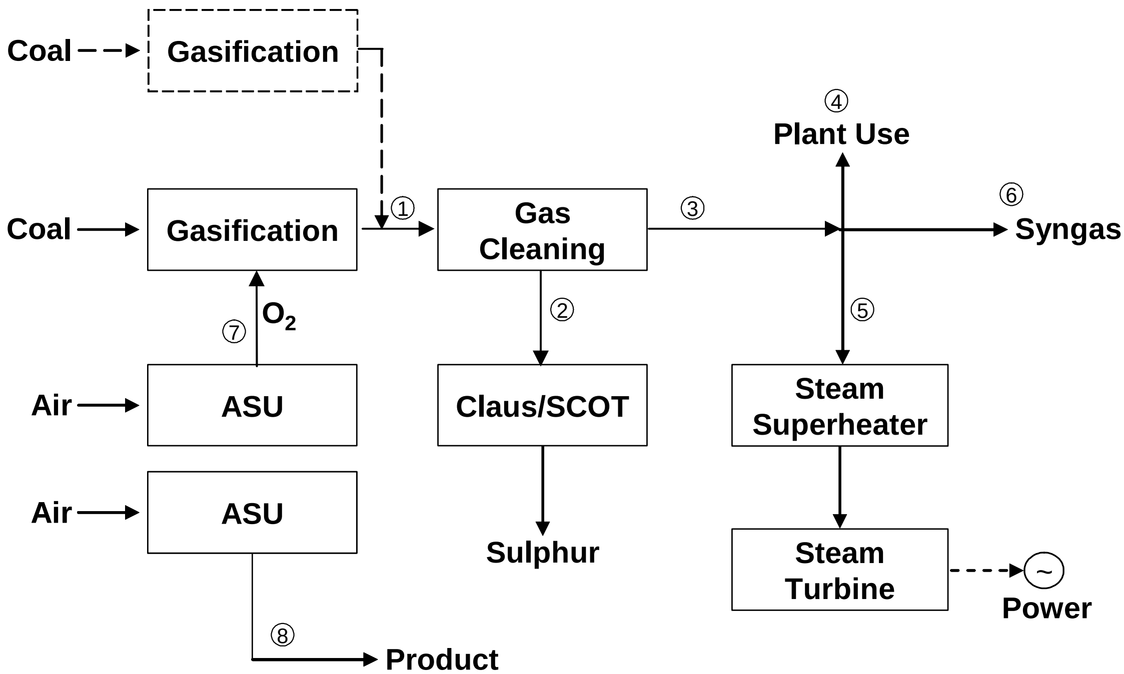

Figure 4. Case 3: Syngas and Oxygen Production using GE/Texaco Gasification

The coal (3030 tons per day) is slurried with water and the slurry is pumped to the gasifier where it is gasified with oxygen. The raw gas exiting the gasifier is water quenched and the quenched output is sent to carbonyl sulfide hydrolysis and then to acid gas removal. The acid gas is sent to a Claus/SCOT combination to recover sulfur. The clean synthesis gas is then split into three streams. One stream is sent to a superheater where high pressure steam is raised for a steam turbine to provide electric power for the plant power requirements, the second stream is for plant fuel, and the third stream is the product synthesis gas. After satisfying plant power needs, only 1.5 MW of power was sent for sales. The quantity of synthesis gas produced by this plant was 1,651 MMBtu per hour. The overall plant efficiency was 56.2 percent on an HHV basis. In addition to production of synthesis gas, this configuration produced additional oxygen for sales. The quantity of oxygen produced for sale was 2,592 tons per day. This quantity of oxygen is what is required to stoichiometrically combust the quantity of synthesis gas produced by this plant. It is assumed that all of the synthesis gas and oxygen would be utilized by the industries being served by the IGI. It can be calculated that 131 pounds of oxygen are required to combust 1 MMBtu of synthesis gas. The numbered streams in Figure 4 show selected material flows for configuration 3. Table 9 details these flows.

Table 10 summarizes the capital and operating costs for this Case 3 configuration. Total capital including non-depreciable capital is estimated to be $444 MM. Coal was assumed to be available at $29 per ton so that coal feed cost for the plant was $31 MM per annum. Operating and maintenance cost, less coal cost, was estimated to be $24 MM per annum.

Table 9. Case 3: Syngas and Oxygen Production, Single Train GE/Texaco Gasification with Spare

Selected Flows, Pound Moles/Hour											
	1				2	3	4	5	6	7	8
	Gasifier Output	Quench Water	Quenched Output	Cooled Gas	Sour Gas	Clean Gas	Plant Gas	Superheater Gas	Product Syngas	ASU Oxygen	Product Oxygen
CH4	3		3	3	0	3	0	1	2		
H20	4,500	28,000	30,950	0	0	0	0	0	0		
H2	7,854		7,854	7,854	39	7,815	63	1,954	5,798		
C0	10,392		10,392	10,392	10	10,381	84	2,595	7,702		
C02	2,889		2,889	2,889	2,860	29	0	7	21		
N2	157		157	157	0	157	1	39	116	688	355
H2S	198		198	198	198	0	0	0	0		
NH3	57		57		0	0	0	0	0		
O2										13,074	6,750
Total	26,048	28,000	52,498	21,492	3,107	18,384	149	4,596	13,640	13,762	7,105
T, Deg F	2500	250	432	432	85	85	85	85	85	59	59
P, atm	41.8		40.2	38.2	1	36.3	35	35	35	44	44

Table 10. Case 3: GE/Texaco Quench (Hot Spare) Syngas and Oxygen Production

Construction Cost Estimate

	$MM
Coal Handling	13
Gasification	101
Gas Cleaning	31
Oxygen Plant	94
Heat Rec/Power Gen	58
Balance of Plant	40
	337
Home Office/Fee	35
Contingency	56
	428
Non-depreciable Capital	16
Total Capital	444

Operating Cost

	$MM/Yr
Coal ($29/Ton)	31
Consumables	2
Labor/OH	4
Local Taxes/Insurance	9
Maintenance/Other	9
	55
By-product Credit	1
Net Operating Cost	54

Coal Input	3030 TPD (AR)
Availability	98%
Syngas Output	1651 MMBTU/Hr
Net Power Output	1.5 MW
Overall Efficiency	56.2% (HHV)
Oxygen	2592 (TPD)

RSP Syngas $/MMBtu	Oxygen Value $/Ton
7.65	0
5.35	35
3.06	70

Power Value $35.6/MWH

Net total operating cost was $54 MM per annum. Using the financial parameters in Table 5 the RSP of the synthesis gas is calculated to be $7.65 per MMBtu if the coproduced oxygen has zero value. If the value of the oxygen is $70 per ton, or $3.00 per thousand cubic feet, then the RSP of the synthesis gas is $3.06/MMBtu. If the value of the coproduced oxygen is only $35 per ton, then the RSP of the synthesis gas is $5.35/MMBtu.

Case 4: Production of Syngas, Oxygen, and Power using E-Gas Gasification

Figure 5 shows a schematic of the Case 4 plant configuration. In this configuration the gasification facility is enlarged so that three products are made. In addition to the synthesis gas and oxygen, electric power is produced for sales. Two trains of ConocoPhillips E-gas gasifiers are used to produce the synthesis gas. The two ASU units are oversized to produce oxygen for gasification and additional oxygen for sales. It is assumed that this two train configuration can provide oxygen and synthesis gas at 98 percent availability and electric power at 75 percent availability. The coal (4,550 tons per day) is slurried with water and the slurry is pumped to the two-stage E-Gas gasifiers where it is gasified with oxygen. The raw gas exiting the gasifier passes through the waste heat boiler (WHB) to recover the sensible heat in the effluent gas and to raise high pressure steam. The WHB output is sent to carbonyl sulfide hydrolysis and then to acid gas removal. The acid gas is sent to a Claus/SCOT combination to recover sulfur. The clean synthesis gas is then split into three streams. One stream is sent to a combined cycle power block consisting of a GE 7F frame gas turbine, a heat recovery steam generator, and a steam turbine for electric power generation. The second stream is for plant fuel, and the third stream is the product fuel gas. After satisfying internal plant power needs, 231 MW of power was sent for sales. The quantity of synthesis gas produced by this plant was 1,808 MMBtu per hour. The overall plant efficiency was 58.7 percent on an HHV basis. In addition to production of synthesis gas, this configuration produced additional oxygen for sales. The quantity of oxygen produced for sale was 2,825 tons per day. This quantity of oxygen is what is required to stoichiometrically combust the quantity of synthesis gas produced by this plant. The numbered streams in Figure 5 show selected material flows for configuration 4. The flows shown are for both trains. Table 11 details these flows.

Table 12 summarizes the capital and operating costs for this Case 4 configuration. Total capital including non-depreciable capital is estimated to be $658 MM. Coal was assumed to be available at $29 per ton so that coal feed cost for the plant was $47 MM per annum. Operating and maintenance cost, less coal cost, was estimated to be $37 MM per annum. Net total operating cost was $81 MM per annum. Using the financial parameters in Table 5 and assuming that the value of the coproduced electric power is $35.6/MWH, the RSP of the synthesis gas is calculated to be $7.02 per MMBtu if the coproduced oxygen has zero value. If the value of the oxygen is $70 per ton, or $3.00 per thousand cubic feet, the RSP of the synthesis gas is $2.45/MMBtu. If the value of the coproduced oxygen is only $35 per ton, then the RSP of the synthesis gas is $4.73/MMBtu.

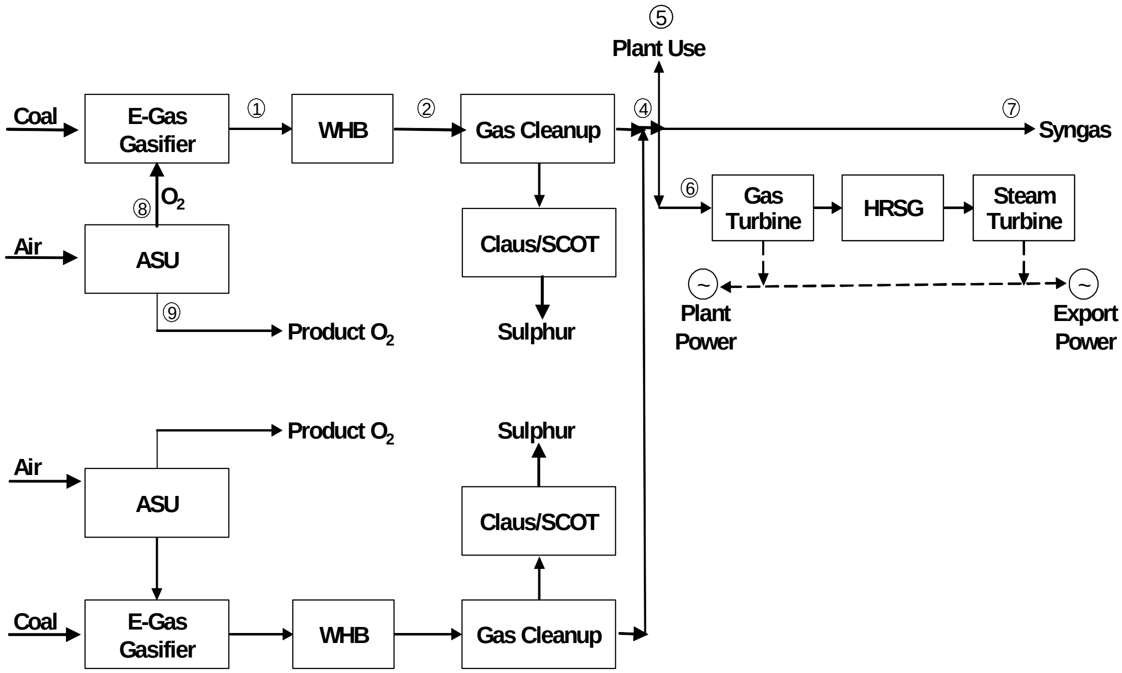

Figure 5. Case 4: Two Train E-Gas Coal Gasification Producing Syngas, Oxygen, and Power

Summary of Analysis Results

Table 13 summarizes the results of this scoping study for the 5 cases analyzed. For the case producing SNG (Case 2), the RSP of the SNG is estimated to be \$6.75/MMBtu (HHV basis). This cost seems quite high but the Case 2 plant is a relatively small facility (about 42 MMSCFD) using coal priced at \$29 per ton compared to a large scale SNG plant like Great Plains that produces over 150 MMSCFD of SNG with low cost lignite.

The plants that produce synthesis gas only [Cases 1 and 1(S)] can produce synthesis gas for around \$5.50/MMBtu.

The plant that produces synthesis gas and oxygen (Case 3) could produce the synthesis gas at an RSP of just over \$3.00/MMBtu if the value of the coproduced oxygen was \$70 per ton (\$3.00/MSCF). If the oxygen value was only half that, at \$35 per ton, then the RSP of the synthesis gas would be \$5.35/MMBtu.

For Case 4 where synthesis gas, oxygen, and electric power are produced, the RSP of the synthesis gas is dependent on the value of the other co-products. If oxygen is valued at \$70 per ton and power is valued at \$35.6/MWH, then the RSP of the synthesis gas would be \$2.45/MMBtu. If the power were valued at \$50/MWH the RSP of the synthesis gas

Table 11. Case 4: Syngas, Oxygen and Power Production, Dual Train E-Gas Gasification, IGCC Power

Selected Flows, Pound Moles/Hour											
	1		2		3	4	5	6	7	8	9
	Gasifier Output	Quench Water	Quenched Output	Cooled Gas	Sour Gas	Clean Gas	Plant Gas	Turbine Fuel	Product Syngas	ASU Oxygen	Product Oxygen
CH4	47		47	47	0	47	0	22	24		
H20	5,193	6,000	10,320	0	0	0	0	0	0		
H2	13,063		13,063	13,063	65	12,998	67	6,174	6,757		
C0	15,318		15,318	15,318	15	15,303	79	7,269	7,955		
C02	4,560		4,560	4,560	4,514	46	0	22	24		
N2	228		228	228	0	228	120	108	0	826	387
H2S	297		297	297	297	0	0	0	0		
NH3	85		85		0	0	0	0	0		
O2										15,689	7,356
Total	38,791	6,000	43,917	33,512	4,891	28,621	267	13,595	14,759	16,515	7,743
T, Deg F	2200	250	351	351	85	85	85	85	85	59	59
P, atrm	41.8		40.2	38.2	1.0	36.3	35.0	16.0	35.0	44	44

Table 12. Case 4: Two Train E-Gas Syngas, Oxygen, and Power Production

Construction Cost Estimate

	$MM
Coal Handling	18
Gasification	129
Gas Cleaning	39
Oxygen Plant	113
Heat Rec/Power Gen	154
Balance of Plant	47
	500
Home Office/Fee	52
Contingency (15 percent)	82
	634
Non-depreciable Capital	24
Total Capital	658

Operating Cost

	$MM/Yr
Coal ($29/Ton)	47
Consumables	2
Labor/OH	8
Local Taxes/Insurance	13
Maintenance/Other	14
	84
By-product Credit	3
Newt Operating Cost	81

Coal Input	4550 TPD (AR)
Availability	98% (Syngas/O_2) 75% power
Syngas Output	1808 MMBTU/Hr
Net Power Output	231 MW
Overall Efficiency	58.7% (HHV)
Oxygen	2825 (TPD)

RSP Syngas $/MMBtu	Oxygen Value $/Ton
7.02	0
4.73	35
2.45	70

Power Value $35.6/MWH

Table 13. Summary of Results

	Case 1	Case 1(S)	Case 2	Case 3	Case 4
Coal Input (TPD)	3030	3030	3030	3030	4550
Availability (%)	85	98	85	98	98 (Syngas and Oxygen) 75 (Power)
Outputs					
Syngas (MMBTU/Hr	1929	1929	—	1651	1808
SNG (MMBTU/Hr	—	—	1739	—	—
Oxygen (TPD)	—	—	—	2592	2825
Net Power (MW)	8.8	8.8	5.3	1.5	231
Efficiency (%HHV)	66.5	66.5	59.6	56.2	58.7
Capital ($MM)	291	359	344	444	658
RSP of Product					
Syngas ($/MMBTU)	5.32	5.53	—	3.06*	2.45*
SNG ($/MMBTU)	—	—	6.75	—	—
Power ($/MWH)	35.6	35.6	35.6	35.6	35.6

*For oxygen @ $70/Ton

would drop to $1.00/MMBtu. If oxygen was only valued at $35 per ton and with power at $35.6/MWH then the RSP of the synthesis gas would be $4.73/MMBtu.

No attempt was made to quantify the expected emissions of NOx and Sox from these coal-based plants. However, it is expected that Sox removal would be 99.5 percent compared to 100 percent for natural gas facilities. For NOx, the coal plants as configured in this analysis do not include SCR units so the expected emissions would be about 0.07 pounds of NOx per MMBtu. This can be compared to about 0.02 pounds for natural gas plants. If SCR units were used in the coal plants the expected NOx emissions would be reduced to 0.02 pounds, comparable to the natural gas facilities.

Conclusions

Natural gas prices have been high for the last two years with prices in the range $5 to $10/MMBtu. Domestic natural gas production is not keeping pace with demand and the U.S. appears to be gearing up for increasing imports of LNG. Natural gas prices are at a level that is affecting domestic industry. Fertilizer manufacturers and other users of natural gas, like glass producers, are closing plants and relocating overseas resulting in job losses. Domestic coal could be used as a substitute for natural gas by providing medium Btu fuel gas or SNG. The concept of an Industrial Gasification Island (IGI) where a central coal-based facility is constructed that produces power, fuel gases, and other chemicals could be a plausible solution. The products from the IGI would then be available to various industries that could be located close to the IGI site.

This scoping study investigated the concept of using an Illinois coal as feedstock to a gasification facility that produced SNG, synthesis gas, and oxygen for use by the glass industry. It was assumed that a commercial scale gasification plant would be used to provide fuel and oxygen for several glass furnaces.

The study analyzed five plant configurations. Two configurations produced only synthesis gas, one produced only SNG, and two configurations produced both synthesis gas and oxygen.

The results of these analyses showed that synthesis gas by itself can be produced from the coal for a RSP of about $5-$5.50/MMBtu. SNG production by itself is more costly at an RSP of about $6.75/MMBtu. If both synthesis gas and oxygen are produced, the RSP of the synthesis gas can be as low as $3.00/MMBtu if the oxygen can be sold for $75 per ton. For an IGI facility that produced electric power, synthesis gas, and oxygen, the RSP of the synthesis gas could be as low as $2.45/MMBtu if the oxygen is sold for $75 per ton and the power for $35.6/MWH.

References

(1) Market Based Advanced Coal Power Systems. Final Report prepared by Parsons, Report Number 10198, December 1998.