Gas-To-Liquid (GTL) Technology Assessment in support of AEO2013

Energy Information Administration
Biofuels and Emerging Technologies Team
January 7, 2013

Outline

- Technology Description
- Planned Capacity
- Performance Characteristics
- Technology Learning
- Production Cost
- Breakeven Analysis
- References
- Appendices A-D

Technology Description

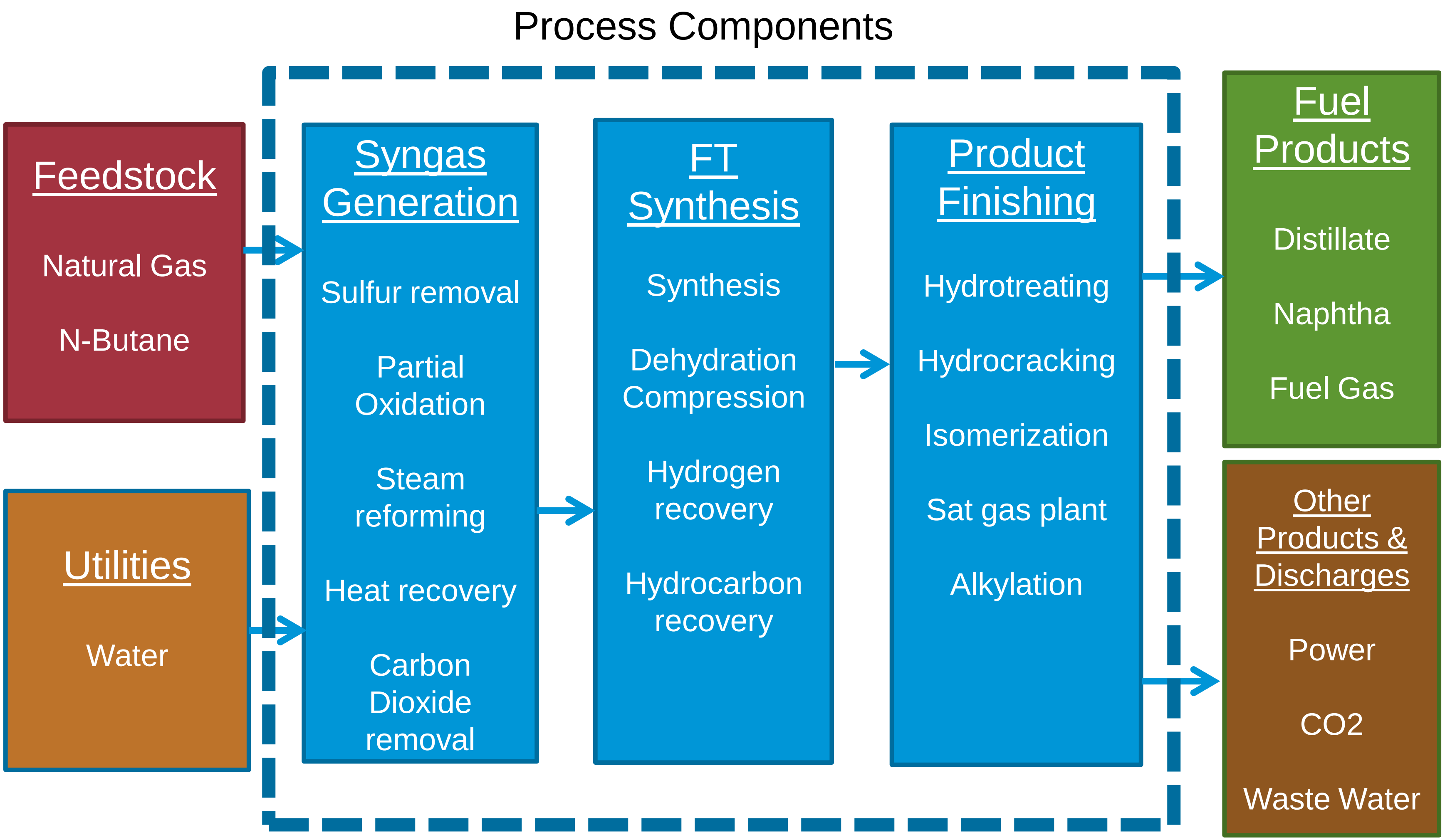
Technology production processes

- Fischer-Tropsch (FT) Synthesis
  - Natural gas to syngas
  - Syngas to hydrocarbons
  - Hydrocarbons to fuel products

Technology Used in AEO2013 (greatest distillate yield)

- Oligomerization
  - Natural gas to syngas
  - Syngas to methanol
  - Methanol to gasoline
- Natural Gas to Dimethyl Ether (DME)
  - Natural gas to syngas
  - Syngas to methanol
  - Methanol to DME

Fischer-Tropsch process overview



Syngas generation

- First stage of the GTL process converts dry natural gas (principally methane) into carbon monoxide and hydrogen, commonly known as synthesis gas (syngas).
  - **$CH_4 + H_2O \rightarrow CO + 3H_2$** steam reforming
  - **$CO + H_2O \rightarrow H_2 + CO_2$** water gas shift reaction
  - **$CH_4 + CO2 \rightarrow 2CO + 2H_2$** hydrogen synthesis
- Zinc oxide is used to remove sulfur from the gas.
- Carbon dioxide formed in water gas shift reaction is recycled back to prevent other side reactions and maintain desired carbon monoxide to hydrogen ratio for FT synthesis.
- Excess carbon dioxide is sent to utilities for sequestration or vented to atmosphere.

FT synthesis & product finishing

- FT process converts synthesis gas into liquid hydrocarbon fuels
  - **$(2n+1)\ H_2 + n\ CO \rightarrow C_nH_{(2n+2)} + n\ H_2O$** FT reaction
- The products of the FT process are C1-C4 hydrocarbons, naphtha, distillate, and waxes
- Waxes are further hydrocracked to produce more distillate, naphtha and C1-C4 hydrocarbons
- C1-C4 hydrocarbons are converted to higher molecular weight hydrocarbons using oligomerization process.

Planned Capacity

Existing and planned capacity data

Project Parameters			Plant Location		Announced Technology Parameters		
Operator	Status	Operational Year	Name / Locality	Country	Nameplate Capacity	Million US$	$/bd
Shell	Operating	1993	Bintulu	Malaysia	12,000	$1,500	$125,000
Sasol	Operating	1994	Sasolburg	South Africa	5,600	ND	ND
Shell	Operating	2006	Bintulu	Malaysia	2,700	ND	ND
Sasol / Chevron[1]	Operating	2006	Oryx	Qatar	34,000	$1,500	$44,118
Shell[2]	Operating	2011	Pearl	Qatar	140,000	$20,000	$142,857
Chevron[3]	Construction	-	Escravos	Nigeria	34,000	$10,000	$294,118
Sasol	Proposed	2018	St Charles	USA	96,000	$14,000	$145.833
Calumet	Proposed	2014	Karns City	USA	1,000	ND	ND

First large Scale GTL facility

Notes:
1. Plant took a number of years to become fully operational
2. Recent capital cost announcements have varied from $18 to $22 billion. Anecdotal evidence indicates it could be even higher.
3. Status is unclear as costs have ballooned significantly but no scope change has been announced.

ND = No Data

Performance Characteristics

Process design data sources

- Bechtel study from 2002 represents a general design that could be integrated with an existing petroleum refinery. It was designed to provide the flexibility of using synthesis gas from coal gasification.
- Results from the Korean study from 2009 that are described in this presentation represent an extremely high yield process that produces nearly entirely diesel. Other results from the paper optimize for different liquid fuels.
- RW Beck study from 2010 was commissioned by EIA in order to compare GTL and CTL on a similar design basis. It represents a good overall design for EIA. However, the mass does not balance and it does not show a full CO_2 balance.

Technology parameters

Parameter	Units of measure	AEO2012	Bechtel (2002)	Korea study (2009)[2]	RW Beck (2010)	AEO2013
Nameplate capacity	b/d	34,000	44,900	32,293	50,000	34,000
Overnight capital cost[1]	$/bd	$76,610	$60,738	$88,013	$96,043	$90,000
Thermal efficiency	%	54	55	84[3]	58	54
Capacity factor	%	85	ND	ND	90	85
Economic lifetime	Years	15	-	-	-	15
Construction lead time	Years	4	-	-	-	4
Feedstock						
Natural gas	MM scf/day	300	412	200	470	300
Raw water	gal/minute		13	ND	ND	
N-Butane	lb/h		3	ND	ND	
Products						
Gasoline	b/d	9,690	17,000	3,958	15,176	9,690
Diesel	b/d	24,310	26,200	28,240	32,656	24,310
Propane	b/d	-	1,700	0	2,168	
CO2	tons/day	-	4,084	-	-	
Net Power	kWh/bbl	-	13.18	0	131.18	0.13

Notes:

1. All costs escalated to 2011$ using CEPCI and U.S. labor costs.
2. Korea study overnight capital cost adjusted to reflect US construction labor conditions.
3. Hydrogen for fuel processing not produced onsite.

Performance characteristics

- Around 2005, multiple major oil companies had designs based around small to medium size projects (35,000-70,000 b/d) with overnight capital cost of ~ $50,000/bd

- Only Shell completed its Pearl project and the scope increased into a ‘megaproject’ (gas field + conversion + petrochemical plant) with overnight capital cost of ~ $140,000/bd

- Since very few project designs have reached the detailed design stage and EIA does not have access to them, we propose to pick round numbers for important parameters that fall between the estimates that are available

Technology Parameters - Gulf Coast Basis	Unit	AEO2012	AEO2013
1st of a Kind Nameplate Capacity	bbl/day	34,000	34,000
Overnight Capital	2011 $/bd	$76,610	$90,000
Thermal Efficiency	percent	54%	54%

Assumed financial parameters

Gulf Coast Basis in 2018	AEO2012	AEO2013
Cost of capital	13.5%	13.5%
Economic lifetime	15	15
Debt to capital ratio	40%	40%

Technology Learning

Technology learning

Not applied to GTL technologies in AEO2013

- Engineering, procurement, and construction (EPC) contractor services, process contingency, operations and maintenance costs will improve as more plants are built
- Bare erected cost, financing costs and inventory capital will remain unchanged
- Cost of capital will change as time advances
- Since bare erected cost is 80 percent of the total cost, the advantage of learning is not significant

Production Costs

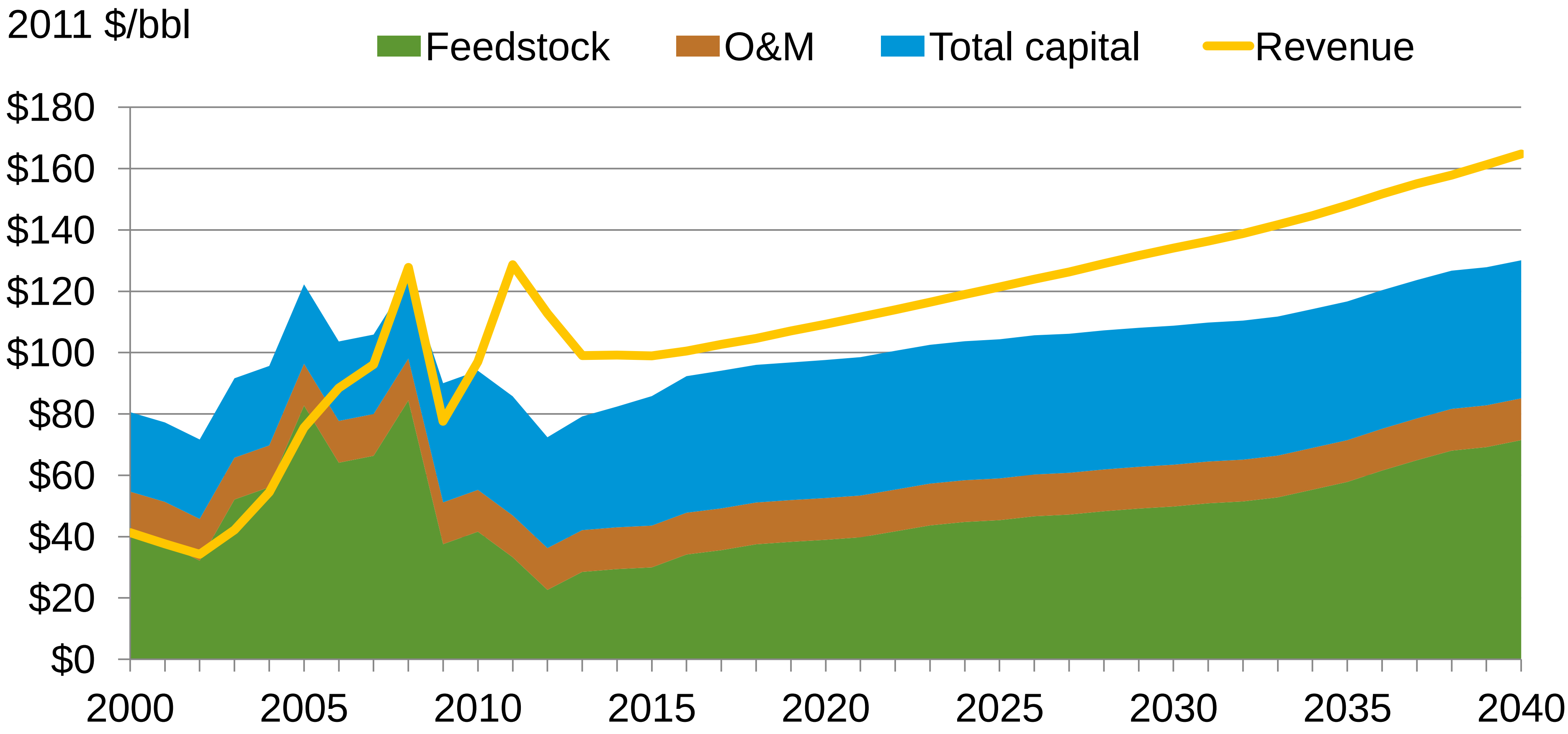
Costs and revenues for prototype plant

Gulf Coast Basis in 2018	AEO2012		AEO2013	
	2011 $/bbl	%	2011 $/bbl	%
Total Cost	91.12	100	92.87	100
Amortized Capital Cost	39.20	43	45.65	49
Feedstock (Natural gas)	41.33	45	34.16	37
Non-Feedstock O&M	10.59	11	12.54	14
Total Revenue	135.58	100	130.54	100
Gasoline	136.11	27	128.67	27
Diesel	135.38	73	129.40	73
Propane	-	-	-	-
Net Sales to Grid	-	-	.01	0

Notes:

1. All costs escalated to 2011$ using CEPCI and U.S. labor costs
2. AEO2012 natural gas price was $4.34/million Btu. AEO2013 is $3.59/million Btu
3. AEO2012 imported low sulfur light crude price was $124/bbl. AEO2013 is $127.30/bbl

GTL production costs over time



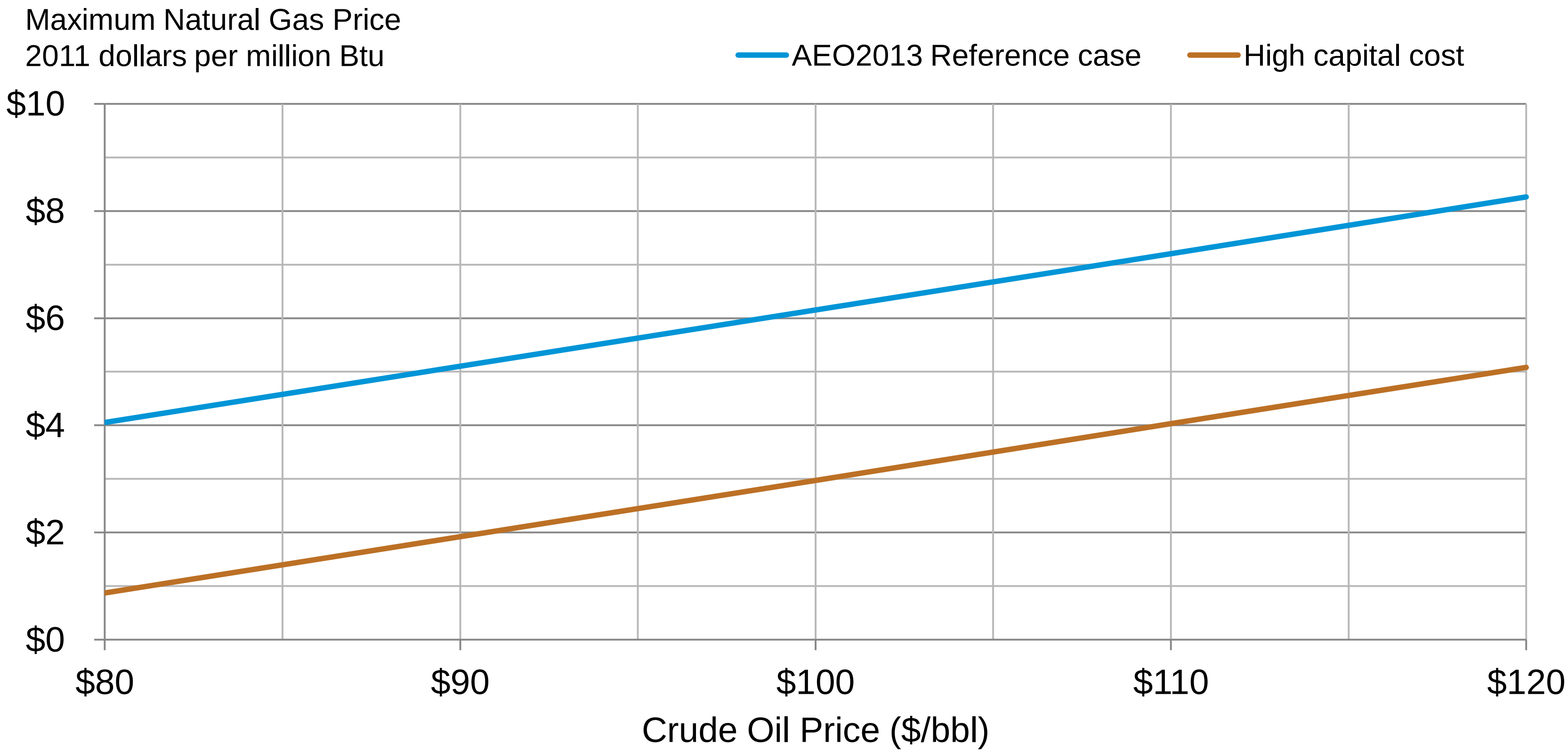
Note: Total capital includes overnight capital of $90,000/bd and cost of financing with ~13.5% cost of capital, 40% debt to capital ratio, and 15 year project life. Revenue comes from mix of gasoline and diesel (27% and 73% respectively).

Breakeven Analysis

Breakeven analysis

- In the following slide, two capital cost scenarios are compared:
  - $90,000/bd represents the AEO2013 reference case
  - $112,500/bd represents the AEO2013 reference case with 25% escalation (high capital cost)
- Production cost analysis is based on a prototype plant. Thus, its accuracy depends strongly on the accuracy of its parameters.
- Breakeven analysis allows multiple scenarios to be compared quickly and easily.

Maximum natural gas price to breakeven



Note: The high capital cost case represents the AEO2013 Reference case with 25% escalation

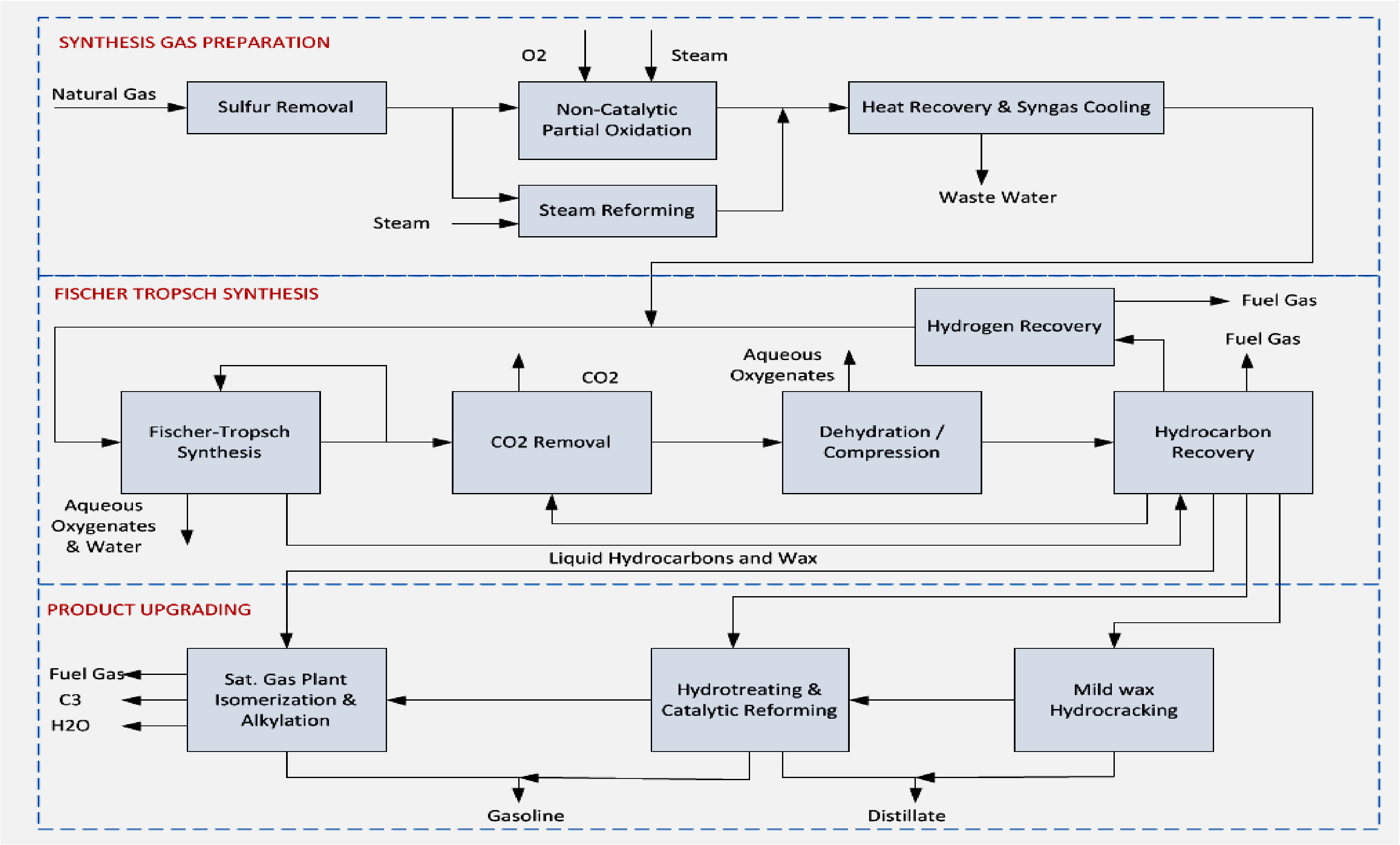
References

References

- Bechtel (2002)
  - Gerald N Choi, Sheldon Kramer and Samual S Tam. “Design and economics of a Fischer-Tropsch plant for converting Natural Gas to Liquid transportation Fuels.” Argonne National Laboratory.
- Korea study (2009)
  - Chul-Jin Lee, Youngsub Lim, Ho Soo Kim, and Chonghun Han. “Optimal Gas-To-Liquid Product Selection from Natural Gas under Uncertain Price Scenarios.” Industrial and Engineering Chemistry Research.
- RW Beck (2010)
  - R.W. Beck. “Fischer-Tropsch Facility - Economic Analysis.” Study commissioned by EIA.

Appendices

Appendix A – Process flow diagram



Source: Adapted from the Bechtel study (2002)

Appendix B – Capital investment summaries

Capital Costs	Bechtel (2002$) 412 MMcf/day		RW Beck (2010$) 470 MMcf/day		Korea (2009$) 200 MMcf/day	
	Million $	Percent	Million $	Percent	Million $	Percent
Installed Equipment	1,491	81	3,613	80	ND	
EPC Services + Contingency	351	19	ND		ND	
Owner's Cost	ND		ND		ND	
Total Overnight Capital	1,842		4,516		2,375	

Appendix C – Operation and maintenance costs

Cost Components	Bechtel (2002$)		RW Beck (2010$)		Korea (2009$)	
	Thousand $	Percent	Thousand $	Percent	Thousand $	Percent
Raw Materials	ND	ND	ND	ND	607,068	75%
Utilities	ND	ND	ND	ND	8,420	1%
Maintenance	ND	ND	ND	ND	66,216	8%
Operating Supplies	ND	ND	ND	ND	9,932	1%
Labor	ND	ND	ND	ND	1,605	1%
Royalty	ND	ND	ND	ND	25,072	3%
Fixed Charges	ND	ND	ND	ND	49,662	6%
Plant OVHD	ND	ND	ND	ND	40,885	5%
Total O&M Cost					809,424	100%

Appendix D – Breakeven analysis details

- In order to perform breakeven analysis with crude oil as independent variable, some relationship between crude and final product prices needs to be assumed
  - For all cases in this presentation, spread between crude and wholesale product prices was taken as the last historical year from AEO2013 and held constant throughout the operational period of the plant (Gasoline is \$33.38/bbl and diesel is \$32.12/bbl)
  - Two other cases have been explored in the past, including a zero spread case (conservative) and a correlation based on multiple AEO cases (aggressive)