The Effect of Manufacturing Costs on the profitability of a Gas-to-Liquid Plant

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Outline

- Introduction
- Process description
- Economical evaluation
- Scenario generation
- Sensitivity analysis
- Conclusions

Introduction

In the last decades, the conversion of natural gas to liquid fuels through the GTL technology, has shown to be an excellent alternative for the use of natural gas.

A typical GTL plant consists of three main units: 1) Syngas production unit, 2) Fischer-Tropsch synthesis unit, and 3) Upgrading unit.

We modelled a typical GTL plant using “UNISIM DESIGN” and performed an economical optimization to determine the optimal equipment sizes, operating conditions, and so on.

Process description

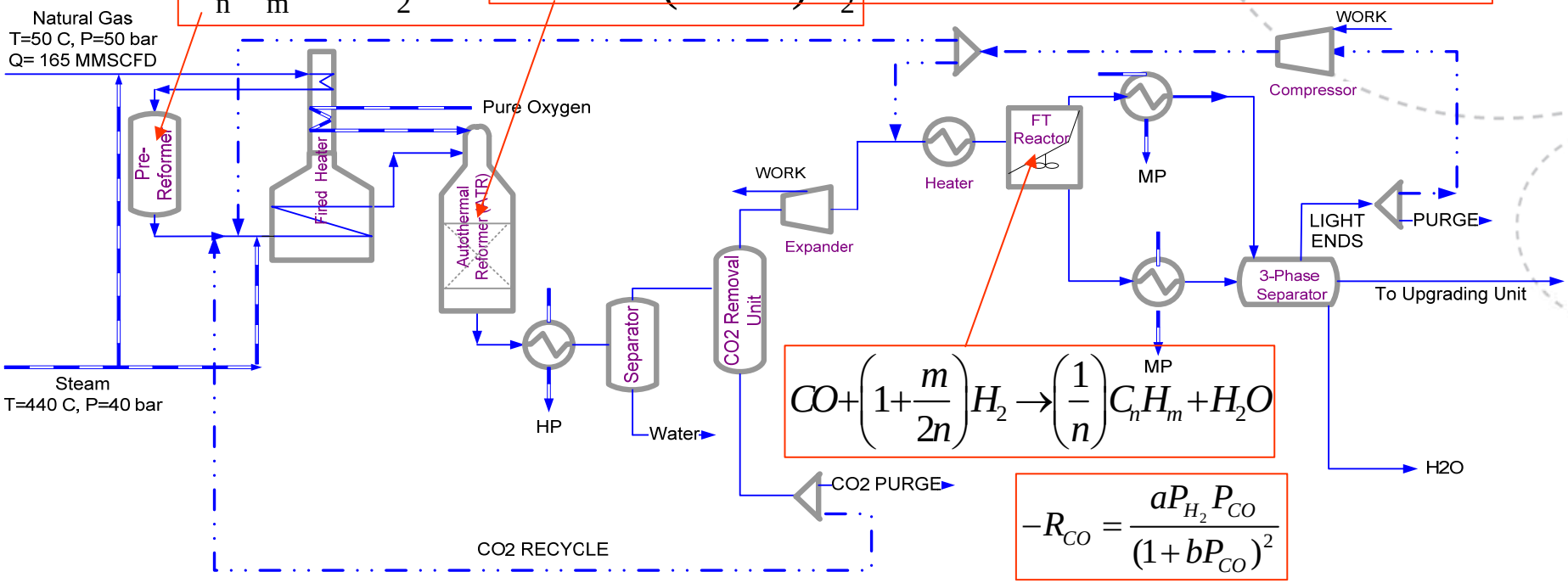
$CH_4 + ½O_2 \rightarrow CO + 2H_2$ (Partial oxidation, -71 kJ/mol)

$CH_4 + H_2O \rightarrow CO + 3H_2$ (steam methane reforming, +206 kJ/mol)

$CO + H_2O \rightarrow CO_2 + H_2$ (water-gas-shift, -41 kJ/mol)

$CH_4 + CO_2 \rightarrow 2CO + 2H_2$ (dry reforming, +247 kJ/mol)

$$C_nH_m + nH_2O \rightarrow nCO + (n+m/2)H_2$$



$$CO + \left(1 + \frac{m}{2n}\right)H_2 \rightarrow \left(\frac{1}{n}\right)C_nH_m + H_2O$$

$$-R_{CO} = \frac{aP_{H_2}P_{CO}}{(1+bP_{CO})^2}$$

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Economical evaluation

1. Capital Cost Estimation

$$\log C_0 = K_1 + K_2 \log(A) + K_3 \log(A)^2$$

C_0 : *Purchased cost for base conditions*

K_1, K_2, K_3 : *Constants*

A : *Capacity*

$$C_{BM} = C_p^0 F_{BM}$$

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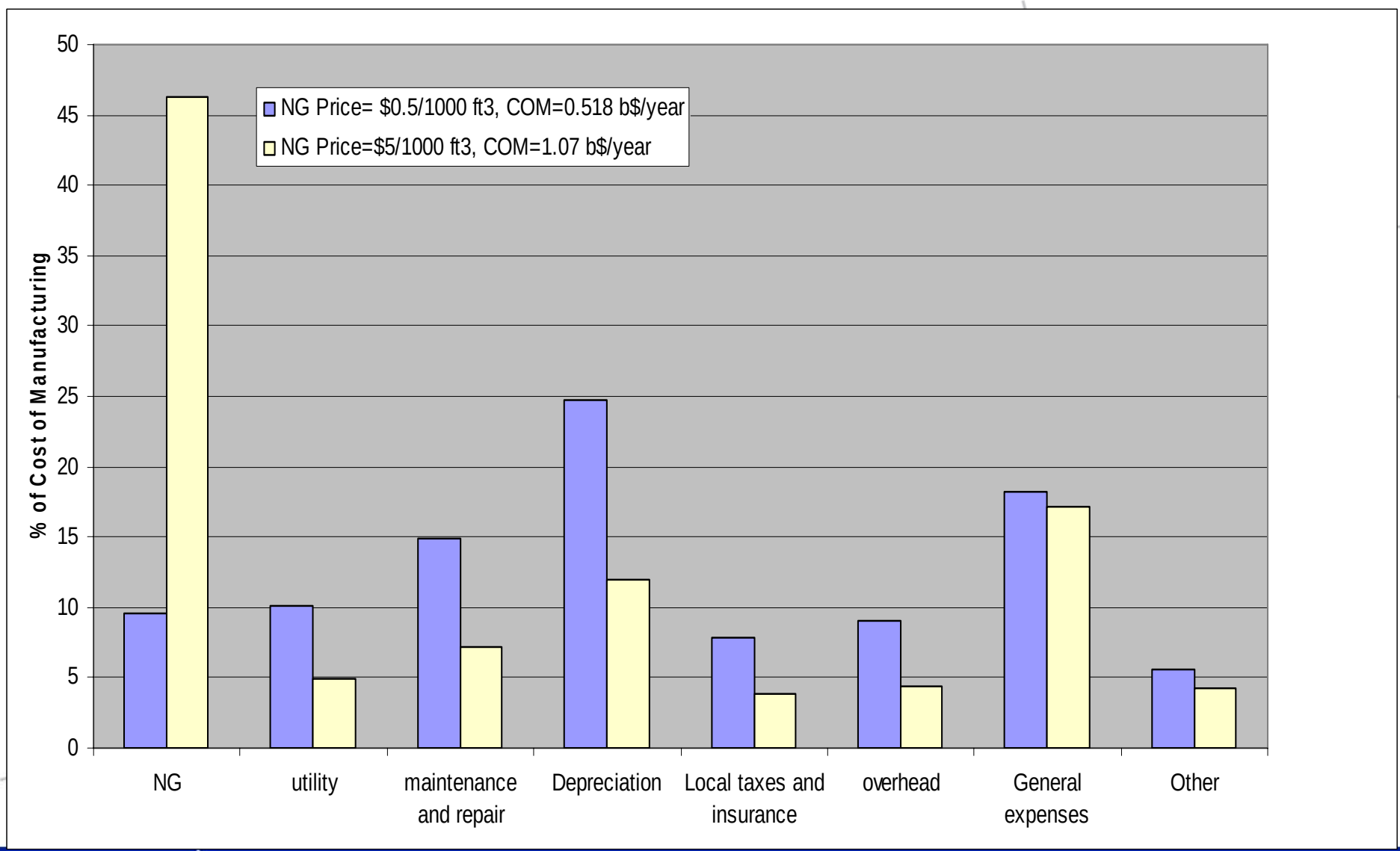
2. Estimation of Manufacturing costs

Cost item	Values used in simulation
1. Direct Costs	
A. Raw materials (C_{RM})	
B. Waste treatment (C_{WT})	
C. Utilities (C_{UT}) • Fuel gas, oil, and/or coal • Electric power • Steam (all pressures) • Process water • Etc.	
D. Operating labor	C_{OL}
E. Direct supervisory and clerical labor	0.18 C_{OL}
F. Maintenance and repair	0.06 FCI
G. Operating supplies	0.009 FCI
H. Laboratory Charges	0.15 C_{OL}
I. Patents and royalties	0.03 COM
Total Direct Manufacturing Costs	$C_{RM}+C_{WT}+C_{UT}+1.33C_{OL}+0.03$ COM$+0.069$ FCI
2. Fixed Costs	
A. Depreciation	0.1 FCI
B. Local taxes and insurance	0.032 FCI
C. Plant Overhead costs	0.708 C_{OL}+0.036 FCI
Total Fixed Manufacturing Costs	$0.708\ C_{OL}+0.168$ FCI
3. General Expenses	
A. Administration costs	0.177 C_{OL}+0.009 FCI
B. Distribution and selling costs	0.11 COM
C. Research and development	0.05 COM
Total General Manufacturing Costs	$0.177\ C_{OL}+0.009$ FCI$+0.16$ COM

$$COM = 0.3037\ FCI + 2.73\ C_{OL} + 1.23\ (C_{UT} + C_{WT} + C_{RM})$$


NG Price= $0.5/1000 ft3, COM=0.518 b$/year
NG Price=$5/1000 ft3, COM=1.07 b$/year
% of Cost of Manufacturing
0
5
10
15
20
25
30
35
40
45
50
NG
utility
maintenance and repair
Depreciation
Local taxes and insurance
overhead
General expenses
Other

The objective function is established as follow:

$$\text{Profit} = \text{Incomes} - \text{Cost Of Manufacturing}$$

And then this objective function has to be maximized to identify the optimal mode of operation for the plant.

$$Pay\ Back\ Time = \frac{fixed\ capital\ investment + start\ up\ cost}{profit\ after\ tax}$$

Optimization results

For a 17000 bbl/day GTL plant we have the following results:

ATR inlet T (C)	700
Oxygen to Carbon ratio	0.55
Steam to Carbon ratio	0.5
ATR outlet T (C)	1050
CO2 removed (kmole/hr)	1300
FT reactor volume (m^3)	2000
FCI (billion $)	1.282

- **Product Distribution**

LPG (C3,C4)	21.22 %
Gasoline (C5-C8)	39.07 %
Naphtha (C9, C10)	11.45 %
Kerosene (C11-C13)	11.16 %
Gas oil (C14-C20)	11.69 %
Fuel Oil (C20+)	5.37 %

- **Carbon efficiency**

Case A) GTL plant without CO2 removal unit

Carbon Efficiency	53 %

Case B) GTL plant with CO2 removal unit

Carbon Efficiency	65 %

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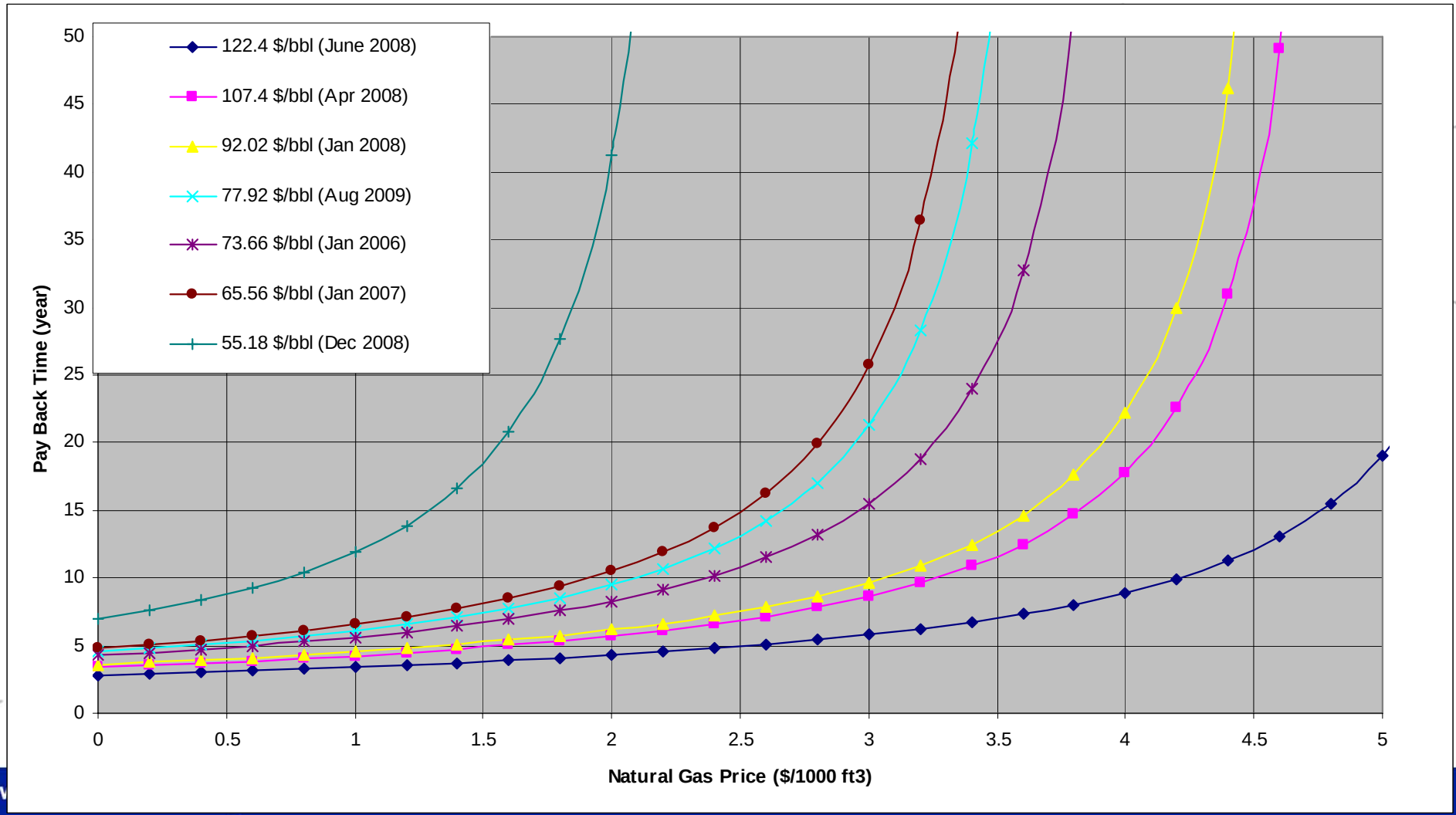
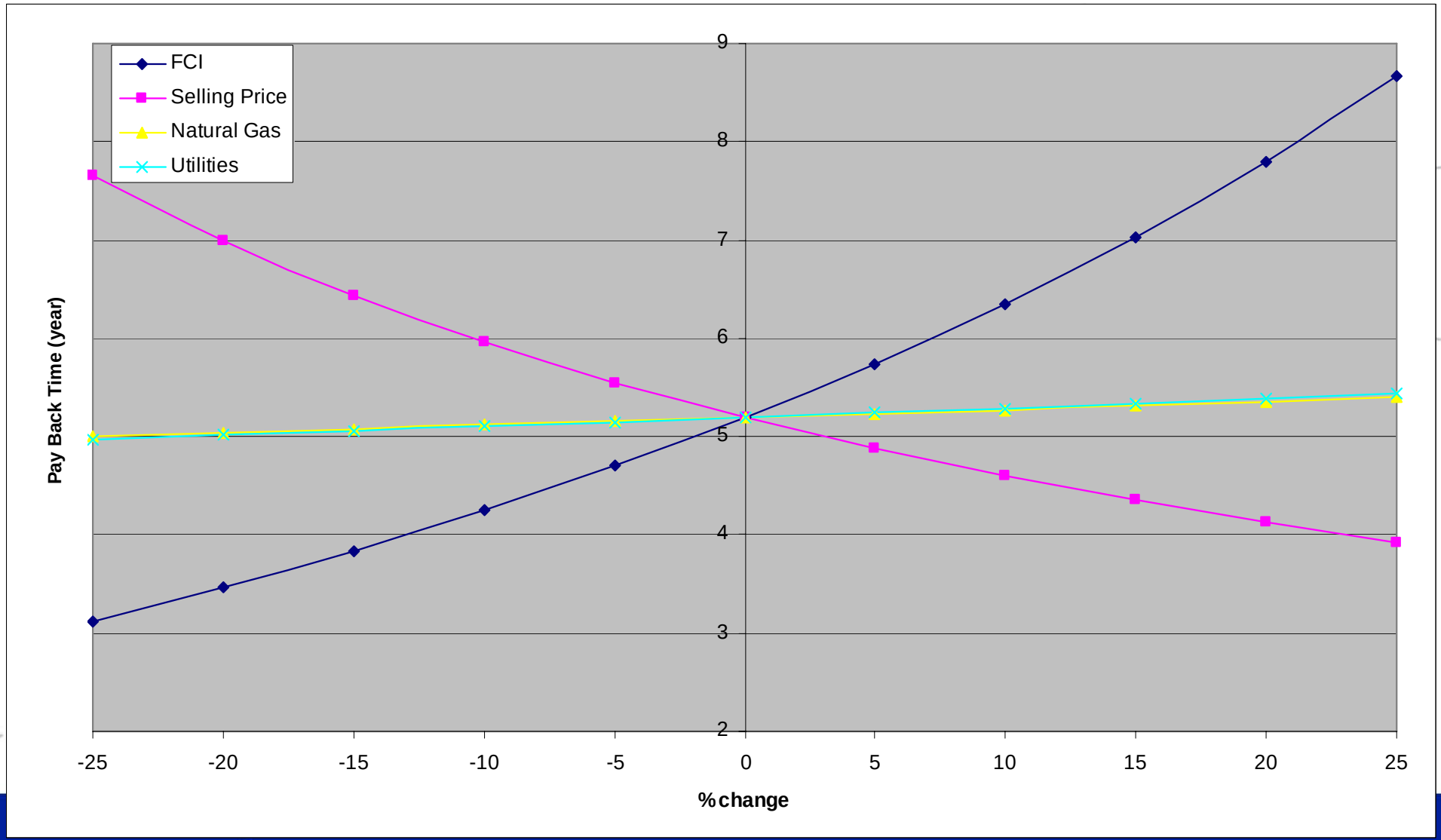
Scenario Generation

Objective: Investigating the effect of “natural gas price” and “product selling price” on the “pay back time”:



Sensitivity Analysis

FCI= 1.282 b$, NG Price=0.5 $/1000 ft^3 ,Product Selling Price= 77.92 $/bbl



Conclusions

1. Optimization results show that removing CO2 from the synthesis gas increases the carbon efficiency of system.

For a cheap natural gas:

2. Pay back time ranges from 3 to 8 years.

3. Sensitivity analysis implies that pay back time is more sensitive to FCI and product selling price rather than natural gas price.

Thank you for your attention

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