SECTION 7
ECONOMICS

SECTION 7

ECONOMICS

This section summarizes the economic evaluation procedures used to analyze the high potential coal liquefaction technologies; it also presents the results of this evaluation. All economic factors are presented in first quarter 1978 dollars.

The economic comparison of four high potential processes includes individual estimates of projected fixed capital investment, total capital investment, operating costs, and profitability measures. Since the primary objective is development of relative economics, all cost and profitability comparisons are presented as ratios. The process with the lowest required capital investment, required product selling price (RPSP) or revenue was assigned a value of 1.0 and the equivalent value for all other processes for the particular economic factor under study was presented as a ratio to the reference process for that economic factor category. This procedure will beome clearer when we begin to discuss the economic comparisons in detail.

For those readers who may want to convert the relative economic factors presented in this report section to the actual dollar values estimated in this study, the projected economics for SRC II are summarized in Table E-1 located in Appendix E.

The results of the Base Case analysis, consisting of the Eastern Region of the Interior Coal Province location, will be presented first. The impact of locating the plants in the Appalachian Region of the Eastern Coal Province and the Powder River Region of the Rocky Mountain Province will then be summarized. Finally, a comparison of projected economics for product supply to the four market areas - Delaware, Chicago, Houston, and San Francisco - will be presented. Sensitivities to key project parameters will also be summarized.

7.1 PROCEDURES

The economic assessments are based on the process configurations previously described in Section 5 and 6 of this report, coupled with the procedures used to develop the comparative economic assessment as described briefly in the following paragraphs.

7.1.1 FIXED CAPITAL INVESTRMENT

The fixed capital investment (FCI) source information for each process has been listed in Section 5. This includes experience generated by Parsons during the development of seven comprehensive conceptual designs plus the results of similar conceptual designs by other contractors. Parsons design projects required the development of preliminary specifications and cost data for over 6,000 major equipment items used in coal conversion plants. Using this equipment cost data, fixed capital estimates were developed for 80 units common to coal liquefaction plants such as coal preparation, acid gas treatment, sulfur removal, fractionation, filtration, and others. This information was used where appropriate to develop the FCIs for this study.

For analytical purposes, the coal conversion complexes were divided into the following four accounts/sections:

- Coal preparation, storage, grinding, and drying
- Process operations
- Utilities
- Facilities

In addition, 12.5% of the constructed cost total for these four accounts sections was added as an allowance for the costs of engineering, home office, fee, and sales tax.

The FCI for a given process plant used a combination of a number of types of estimating procedures as described below.

7.1.1.1 Coal Preparation, Storage, Grinding and Drying

The FCIs for these units were developed based on analysis of the results of similar units contained in the nine conceptual designs/economic evaluations generated by major contractors. Where required, the units were adjusted, scaled, and escalated.

7.1.1.2 Process Operations

The primary coal conversion units such as the coal hydroliquefaction, coal extraction, coal catalytic hydroliquefaction, gasification, and production of liquids from synthesis gas are specific to the separate processes. The FCIs were taken with judgement applied from major contractors' conceptual designs. Where required, the sizes of the units were scaled up or down. The costs were escalated to a first quarter 1978 basis. There are a large number of other types of units common to coal conversion plants; examples include acid gas removal units, sulfur plants, oxygen plants, filtration units, fractionation units, and product upgrading/refining units.

For the upgrading/refining units, FCIs were obtained by careful analysis and judgemental adjustment of prior inhouse and petroleum industry refining experience plus, where appropriate, use of experimental data generated while processing coal-derived liquids in refinery type operations.

An example of use of prior inhouse refining experience is catalytic reforming as a step to produce gasoline. Hydrotreating is an example of use of experimental data to define capacity and economics of a refinery type operations when processing coal-derived liquids. Here the experimental data developed in DOE/ERDA/OCR sponsored programs were used to establish design parameters such as space velocity, hydrogen consumption, and others. For the other important supporting process units such as acid gas removal units, etc., the FCIs were developed by analysis and adjustment of prior related conceptual designs/economic evaluations.

7.1.1.3 Utilities

A utilities balance was developed for each candidate process. The FCIs for the utilities section was then developed from unit costs of prior conceptual designs/economic evaluations for related processes. Each case was analyzed prior to establishment of the FCI and suitable adjustments, and escalations made.

7.1.1.4 Offsites and General Facilities

Allowances for offsites and general facilities were developed based on the costs of similar facilities in related prior conceptual designs. The source costs were escalated to first quarter 1978 dollars.

Offsites and ancillaries include buildings, roads, utilities, communications, rolling stock, and related facilities required to efficiently service the plant operation and population.

7.1.2 TOTAL CAPITAL REQUIREMENTS

In addition to fixed capital investment, total capital requirements include initial charges of catalysts and chemicals, start-up costs, construction financing, and provision for working capital. Procedures for developing these costs are summarized below.

7.1.2.1 Initial Charges of Catalysts and Chemicals

The cost of the initial charge of catalyst and chemicals (C & C) was developed for each process. To develop the costs, each unit was analyzed and the quantities of initial C & Cs required were estimated and priced. The annual consumption of C & Cs was also estimated.

7.1.2.2 Start-up Costs

An allowance of 5% of FCI was used for start-up costs.

7.1.2.3 Construction Financing

The construction financing was calculated based on a five-year construction period, with the rate of funds drawdown as follows:

Year	Percent Drawdown	Cumulative Percent Drawdown
1	8	8
2	17	25
3	26	51
4	29	80
5	20	100

The cost of construction financing is based on 9% interest for funds drawn and a loan commitment fee of 0.75% for funds committed but not yet drawn.

7.1.2.4 Working Capital

Working capital consisted of the cost of:

- 15 days feed coal inventory
- 30 days inventory of liquid product
- Cost of spare parts inventory = 1% of FCI
- 30 days accounts receivable
- 30 days budget for current expenses

- 30 days credit for accounts payable

Working capital funds were borrowed for the project operating life.

7.1.3 OPERATING COSTS

Operating costs consist of the cost of purchased coal, materials and supplies, operating labor, maintenance, G & A overhead, property taxes and insurance, and miscellaneous. Methods of estimating these factors are described below.

7.1.3.1 Coal Cost

The coal conversion plants are conceived to be located close to mines. The analysis is based on the following delivered costs of coal to the project:

o Eastern Region of the Interior Coal Province	$22.00
o Appalachian Region of the Eastern Coal Province	$27.00
o Powder River Region of the Rocky Mountain Coal Province	$ 8.50

7.1.3.2 Materials and Supplies

Factors used were:

- Raw water, $0.30/1000 gallons
- Operating Supplies, 30% of operating labor

7.1.3.3 Operating Labor

The staffing was estimated for each plant. The operating labor wage rate used was $8.00 per hour. The payroll burden was 35% of operating and maintenance labor.

7.1.3.4 Maintenance

Maintenance costs used were:

- Process units, 4% of FCI
- Offsites and Ancillaries, 2% of FCI

7.1.3.5 G & A Overhead

An allowance of 1.5% of the total manufacturing cost was used for the G & A.

7.1.3.6 Property Taxes and Insurance

An allowance of 2.75% of FCI was used for property taxes and insurance.

7.1.4 REQUIRED PRODUCT SELLING PRICE

The RPSP was calculated using the capital investments and operating costs previously described plus the following parameters:

- Design/construction period = 5 years
- Operating period = 20 years
- Total project life = 25 years

- Depreciation = 13 years useful life; double declining balance method
- Debt = 65% of total investment, repaid in equal installments over the 20-year operating life
- Equity = 35% of total investment
- Interest rate = 9%
- Discounted cash flow (DCF) rate of return on equity = 12%
- By-product credits:
  - Ammonia = $140/ton
  - Sulfur = $ 60/short ton

The RPSP necessary to pay expenses and provide a 12% DCF rate of return on equity was predicted using a computer program. An allowance for inflation for the life of the project was not included in the RPSP model.

7.1.5 POSSIBLE ANNUAL REVENUE

A brief assessment was made of the possible product market values. Market values were assigned to LPG and liquid fuels based on review of published information plus, in some cases, discussion with suppliers and potential users. The values were based on the coal-based fuels being competitive with petroleum based fuels having similar characteristics. Confirmation of the marketability and market values of coal derived fuels is required.

In the case of SNG, the primary evaluation was based on a market value of $3.25 per thousand cubic feet (MCF). This judgement value is intermediate between intrastate natural gas prices and the value allowed for SNG from naphtha. The true market value for SNG from coal must await commercialization.

The market values used are summarized in Table 7-1; values are presented for four markets consisting of Delaware, Chicago, Houston, and San Francisco.

7.1.6 BENEFIT COST RATIO

Benefit/cost (B/C) ratios were calculated for each high potential process as follows:

$$B/C = \frac{\text{Possible Annual Market Value of Products}}{\text{Required Annual Revenue to Yield 12\% DCF on Equity}}$$

The B/C ratio is presented to rank the processes based on projected profitability levels. When the B/C ratio is greater than one, the projected DCF based on the market value of products is greater than 12%. The higher the B/C ratio, the greater the projected DCF (profitability).

7.2 RESULTS: BASE CASE, PLANT GATE ECONOMICS

The results for projected plant gate economics for the Eastern Region of the Interior Coal Province follow.

7.2.1 FIXED CAPITAL INVESTMENT

The predicted ratios of the fixed capital investments for the four processes are shown in Table 7-2; the relative contributions, on an index basis, of the separate plant sections are also shown. The results indicate that the processes array themselves in the following order of increasing FCIs:

1. SRC II based
2. H-Coal based
3. CSF based
4. Fischer-Tropsch based

7.2.2 TOTAL CAPITAL INVESTMENT

The predicted ratios of total capital investments for the processes are presented in Table 7-3. The relative contributions of the separate contributors to the total investment are given on an index basis.

The ranking of the processes is identical to that obtained for fixed capital investment.

7.2.3 OPERATING COSTS

The ratios of the total operating costs are shown in Table 7-4. Cost contribution by the cost items are shown on an index basis. The processes, ranked in order of increasing operating costs, array themselves as follows:

1. SRC II based
2. H-Coal based
3. CSF based
4. Fischer-Tropsch based

7.2.4 REQUIRED PRODUCT SELLING PRICE (RPSP)

The ratios of total required annual revenues and therefore, unit Btu RPSP are given in Table 7-5. The sub-group contributions are shown on an index basis. The ranking, in order of increasing unit Btu RPSP is:

1. SRC II based
2. H-Coal based
3. CSF based
4. Fischer-Tropsch based

7.2.5 POSSIBLE ANNUAL REVENUE

The ratios of possible annual total revenues for the 600 billion Btu per day of products are presented in Table 7-6. The contribution by the individual products are shown on an index basis. Here the ranking, in decreasing order of possible revenues, is:

1. Fischer-Tropsch based
2. H-Coal based
3. CSF based
4. SRC II based

7.2.6 BENEFIT COST (B/C) RATIO

The ratio of possible annual market revenue to required annual revenue at 12% DCF was calculated for each process, base case. This important ratio is a direct function of projected profitability.

The predicted B/C ratios are:

Process	B/C Ratio
Fischer-Tropsch based	0.88
H-Coal based	0.88
SRC II based	0.85
CSF based	0.77

The results indicate that the B/C ratios for Fischer-Tropsch, H-Coal, and SRC II are approximately equivalent, with CSF showing an approximately 10% lower value. For the project parameters used, all of the process plants are indicated to yield a DCF lower than 12% on equity.

The sensitivity of the B/C ratio to SNG market value is shown in Table 7-7 and Figure 7-1. The sensitivity was projected over a SNG market value range of $2.25 to $4.25 per MCF. The results show that the B/C ratios for the configuration of Fischer-Tropsch used for this study predictably is most sensitive to SNG market value. At a $4.25/MCF SNG value, the B/C ratio is approximately one. It also indicates that H-Coal and SRC II based plants show similar B/C ratios and similar sensitivity slopes; for CSF the B/C ratio is lower than for H-Coal and SRC II.

7.3 RESULTS: BASE CASE, DELIVERED

A secondary objective of the analysis was to compare the projected technical and economic performances of the high potential processes when delivering fuels to four market areas. To accomplish this, a brief survey of fuel transportation costs was conducted. For reference, the results are summarized in Appendix B.

The first example to be presented is delivery of products from the Eastern Region of the Interior Coal Province to the Chicago marketing area terminal. To illustrate this case, the plant site was arbitrarily conceived to be located in New Athens, Illinois; information is available for this site which was earlier selected for potential use in the government demonstration plant program.

Preferred transportation methods and costs were investigated for movement of all products from New Athens to Chicago. Transport methods investigated included pipelines, barge, and rail. The transportation costs were based on the results of contacts with railroads, pipeline and barge companies, review of available published literature, and inhouse information.

The results indicate that the costs of transporting the products represent the following percentages of the plant gate RPSPs and B/C ratios:

Item	Process			
	SRC II based	H-Coal based	CSF based	Fischer-Tropsch based
Transportation Cost as % of Plant Gate RPSP	4	4	3	6
Ratio of Delivered RPSP	1.00	1.16	1.23	1.46
B/C Ratios, Delivered Basis	0.82	0.84	0.72	0.85

The ranking of the processes is therefore the same based on delivered costs as earlier developed for plant gate costs.

7.4 RESULTS: EFFECT OF ALTERNATE LOCATIONS

An additional secondary objective of the study was to assess the performance and projected economics for the processes in the Appalachian Region of the Eastern Coal Province and the Powder River Region of the Rocky Mountain Province.

Differences which result from operation of the process plants in the three separate regions include coal characteristics, cost of coal, product slate, labor costs, preferred method of supplying the utilities, and others. The effects of these differences were discussed in Section 5.

The effects of the different locations were analyzed. Table 7-8 summarized projected values of FCI ratio, predicted thermal efficiency, and the required feed coal and oxygen rates for the three regions. Table 7-9 shows the relative contributions of the separate accounts to RPSP ratio for the Eastern Coal Province case and Table 7-10 presents similar data for the Rocky Mountain Region.

The summary comparison present in Table 7-11 shows that the RPSP ratios vary significantly between regions, with the Appalachian area the most costly area in which to produce and the Western Rocky Mountain Region the least expensive and giving the SRC II process a greater advantage in this area. The shift in ratios is mainly attributed to lower coal prices in the West, $8.25/ton versus $27.00/ton in the Appalachian Region of the Eastern Coal Province; the western coal used for this study was largely surface mine produced while the Appalachian area used significant underground mining.

Table 7-11 ratios combined with Table E-1 (Appendix E) key cost data i indicate lowest potential product costs at the western U.S. site, intermediate costs in the Interior region and somewhat bigger costs in the Appalachian region.

7.4.1 DELIVERED COST, APPALACHIAN AND ROCKY MOUNTAIN REGIONS

Delivery costs for the Appalachian location plant products to the Dover, Delaware marketing center are based on pipeline deliveries. These are approximately double the delivery costs for the base case location to Chicago.

The Western Rocky Mountain Region product delivery to San Francisco, also by pipeline, costs approximately four times that for the base case location to Chicago.

Tabulations of transportation cost percentages and ratios of delivered RPSP are shown below:

Item	Process			
	SRC II based	H-Coal based	CSF based	Fischer-Tropsch based
Appalachian Region to Dover, DE:				
Transportation costs as % of Plant Gate RPSP	9	8	7	5
Ratio of Delivered RPSP	1.00	1.16	1.25	1.37
B/C Ratios, Delivered Basis	0.75	0.77	0.69	0.81
Western Rocky Mountain Region to San Francisco:				
Transportation cost as % of Plant Gate RPSP	22	19	17	18
Ratio of Delivered RPSP	1.00	1.20	1.27	1.41
B/C Ratios Delivered Basis	0.87	0.87	0.79	0.91

Table 7-12 summarizes the projected B/C ratios for plant gate and for delivering of products to the assigned marketing areas. The largest decline in B/C ratios for delivered as compared to plant gate operations occurs in the Western Region.

Table 7-1 - Possible Fuel Market Values
(First Quarter 1978)

Item	Possible Unit Market Value			
	Delaware	Chicago	Houston	San Francisco
SNG ($/MCF)	3.25	3.25	3.25	3.25
LPG_3 ($$/bbl)	12.00	12.50	12.00	12.00
LPG_4 ($/bbl)	13.00	13.50	13.00	13.00
Gasoline ($/bbl)	17.15	18.00	16.75	17.75
Distillate Fuel Oil No. 2 ($/bbl)	16.00	15.75	14.50	15.00
Distillate Fuel Oil No. 4 and Heavy ($/bbl)	14.50	15.00	14.50	14.50
Residual Fuel Oil ($/bbl)	12.00	12.00	12.00	11.00

Table 7-2 - Ratios of Estimated Fixed Capital Investments

Item	Relative Contribution to FCI			
	SRC II Based	H-Coal Based	CSF Based	Fischer-Tropsch Based
Coal Preparation, Storage, Grinding and Drying	0.06	0.06	0.06	0.05
Process Operations	0.62	0.78	0.91	1.20
Steam and Power Generations	0.09	0.10	0.13	0.15
Offsites and General Facilities	0.12	0.13	0.15	0.10
Total Constructed Cost	0.89	1.07	1.25	1.50
Add: Engineering, Home Office, Fee and Sales Tax @ 12.5%	0.11	0.13	0.15	0.20
Ratio to SRC II	1.00	1.20	1.40	1.70

Table 7-3 - Ratios of Total Capital Investment
Eastern Region of the Interior Coal Province (Base Case)

Item	Relative Contribution to Total Investment			
	SRC II Based	H-Coal Based	CSF Based	Fischer-Tropsch Based
Fixed Capital Investment	0.75	0.91	1.07	1.29
Initial Catalysts	0.01	0.01	0.01	0.02
Start-up Costs	0.05	0.05	0.06	0.07
Interest During Construction	0.10	0.13	0.13	0.15
Commitment Fee	0.02	0.02	0.03	0.03
Total Depreciation Investment	0.93	1.12	1.30	1.56
Working Capital	0.07	0.08	0.10	0.12
Ratio of Total Capital Investment to SRC II	1.00	1.20	1.40	1.68

Table 7-4 - Ratios of Operating Costs

Item	Relative Contribution to Operating Cost			
	SRC II Based	H-Coal Based	CSF Based	Fischer-Tropsch Based
Coal	0.63	0.67	0.73	0.75
Materials, Supplies, and Utilities				
Operating Supplies	0.01	0.01	0.01	0.01
Utilities	0.01	0.01	0.01	0.01
Maintenance Materials and Contract Labor	0.08	0.09	0.11	0.13
Catalysts and Chemicals	0.04	0.07	0.04	0.03
Total Material, Supplies and Utilities	0.14	0.18	0.17	0.18
Labor				
Operating Labor and Supervision	0.02	0.03	0.02	0.02
Maintenance Labor and Supervision	0.04	0.05	0.05	0.07
Payroll Burden	0.02	0.02	0.02	0.03
Plant Overhead/Administration	0.05	0.06	0.06	0.07
Total Labor Costs	0.13	0.16	0.15	0.19
G and A Overhead	0.01	0.01	0.02	0.02
Property Taxes and Insurance	0.09	0.11	0.13	0.15
Ratio to SRC II	1.00	1.13	1.20	1.29

Table 7-5 - Ratios of Required Product Selling Price

Item	Relative Contribution to Unit Btu RPSP			
	SRC II Based	H-Coal Based	CSF Based	Fischer-Tropsch Based
Capital[a]	0.38	0.46	0.54	0.63
Coal	0.42	0.44	0.49	0.49
Operations[b]	0.24	0.31	0.31	0.36
By-product Credit[c]	-0.04	-0.05	-0.06	-0.04
Ratio of RPSP to SRC II	1.00	1.16	1.28	1.44

[a] Amortization; borrowing cost, 65% of the total investment borrowed at 9% interest, with principal repaid in equal installments over the 20 year project term; working capital, borrowed for the 20 year term; loan commitment fee of 0.75% on funds not yet drawn; 12% return on equity funds; income tax.

[b] Labor, utilities, maintenance labor and materials, property taxes, insurance, catalysts and chemicals, supplies, G and A overhead, plant overhead, payroll burden.

[c] By-product credit based on: sulfur, \$60/ton; ammonia, \$140/ton.

Table 7-6 - Ratios of Possible Annual Revenues
Eastern Region of Interior Coal Province (Base Case)

Item	Relative Contribution to Annual Revenue			
	SRC II Based	H-Coal Based	CSF Based	Fischer-Tropsch Based
SNG (%)	0.32	0.36	0.30	0.74
LPG_3	0.04	0.04	0.10	-
LPG_4	0.02	0.11	0.02	0.12
Gasoline	0.13	0.26	0.27	0.46
No. 2 Fuel	-	-	-	0.05
Heavy Fuel Oil	-	0.04	-	0.02
Residual Fuel Oil	0.44	0.33	0.40	-
Oxygenates	-	-	-	0.07
By-products	0.05	0.06	0.07	0.04
Ratio of Possible Total Revenue to SRC II	1.00	1.20	1.16	1.48

Table 7-7 - Sensitivity of Benefit/Cost Ratio to SNG Market Value Eastern Region of the Interior Coal Province (Base Case)

Item	Process			
	SRC II Based	H-Coal Based	CSF Based	Fischer-Tropsch Based
SNG Production as % of Total Fuels, Btu Basis	26	28	25	53
Benefit/Cost Ratio:				
at $4.25/MCF SNG Price	0.93	0.96	0.83	1.01
at $3.25/MCF SNG Price (Base Price)	0.85	0.88	0.77	0.88
at $2.25/MCF SNG Price	0.77	0.80	0.71	0.74

Table 7-8 - Alternate Location Comparison

Process	Eastern Region Interior Coal Province (Base Case)				Appalachian Region Eastern Coal Province				Western Rocky Mountain Region			
	TCI Ratio	Thermal Efficiency HHV Basis (%)	Coal Feed Rate (TPD)	Oxygen Feed Rate (TPD)	TCI[a] (% Change)	Thermal Efficiency (%)	Coal Feed Rate (TPD)	Oxygen Feed Rate (TPD)	TCI[a] (% Change)	Thermal Efficiency (%)	Coal Feed Rate (TPD)	Oxygen Feed Rate (TPD)
SRC II Based	1.0	78	30,630	3,145	-2	79	27,873	3,050	+10	71	33,187	3,800
H-Coal Based	1.2	76	32,360	4,620	-1	75	30,325	4,310	+15	60	36,456	5,790
CSF Based	1.6	67	35,710	8,755	-2	68	32,596	8,590	+11	46	38,926	10,770
Fischer-Tropsch Based	1.7	60	36,350	21,608	-2	67	33,069	22,620	+1	59	39,975	25,960

[a] TCI, percentage change from base case.

Table 7-9 - Ratios of RPSP - Appalachian Region of Eastern Coal Province

Item	Relative Contribution to Unit Btu RPSP			
	SRC II	H-Coal	CSF	Fischer-Tropsch
Capital[a]	0.36	0.43	0.51	0.61
Coal	0.45	0.30	0.52	0.53
Operations[b]	0.23	0.29	0.30	0.33
By-product Credit[c]	-0.04	-0.06	-0.06	-0.05
Ratio of RPSP to SRC II	1.00	1.17	1.27	1.42

Table 7-10 - Ratios of RPSP - Western Rocky Mountain Region

Item	Relative Contribution to Unit Btu RPSP			
	SRC II	H-Coal	CSF	Fischer-Tropsch
Capital[a]	0.52	0.65	0.73	0.81
Coal	0.22	0.23	0.25	0.25
Operations[b]	0.32	0.41	0.41	0.46
By-product Credit[c]	-0.06	-0.06	-0.08	-0.06
Ratio of RPSP to SRC II	1.00	1.23	1.33	1.46

[a]Depreciation; borrowing cost, 65% of the total investment borrowed at 9% interest, with principal repaid in equal installments over the 20-year project term; working on funds not yet drawn; 12% return on equity funds; income tax.
[b]Labor, utilities, maintenance labor and materials, property taxes, insurance, catalysts and chemicals, supplies, G&A overhead, plant overhead, payroll burden.
[c]By-product credit based on: sulfur, $60/ton; ammonia, $140/ton.

Table 7-11 - Regional Comparison of RPSP Ratios

Region	Base Process			
	SRC II	H-Coal	CSF	Fischer-Tropsch
Eastern (Base Case)	1.00	1.16	1.28	1.44
Appalachian	1.04	1.22	1.32	1.48
Western	0.81	0.99	1.18	1.07

Table 7-12 - Regional Comparison of B/C Ratios

Region	Cost Type	Base Process			
		SRC II	H-Coal	CSF	Fischer-Tropsch
Eastern (Base Case)	Plant Gate	0.85	0.88	0.77	0.88
	Delivered	0.82	0.84	0.72	0.85
Appalachian	Plant Gate	0.82	0.83	0.74	0.85
	Delivered	0.75	0.77	0.69	0.81
Western	Plant Gate	1.06	1.03	0.92	1.07
	Delivered	0.87	0.87	0.79	0.91

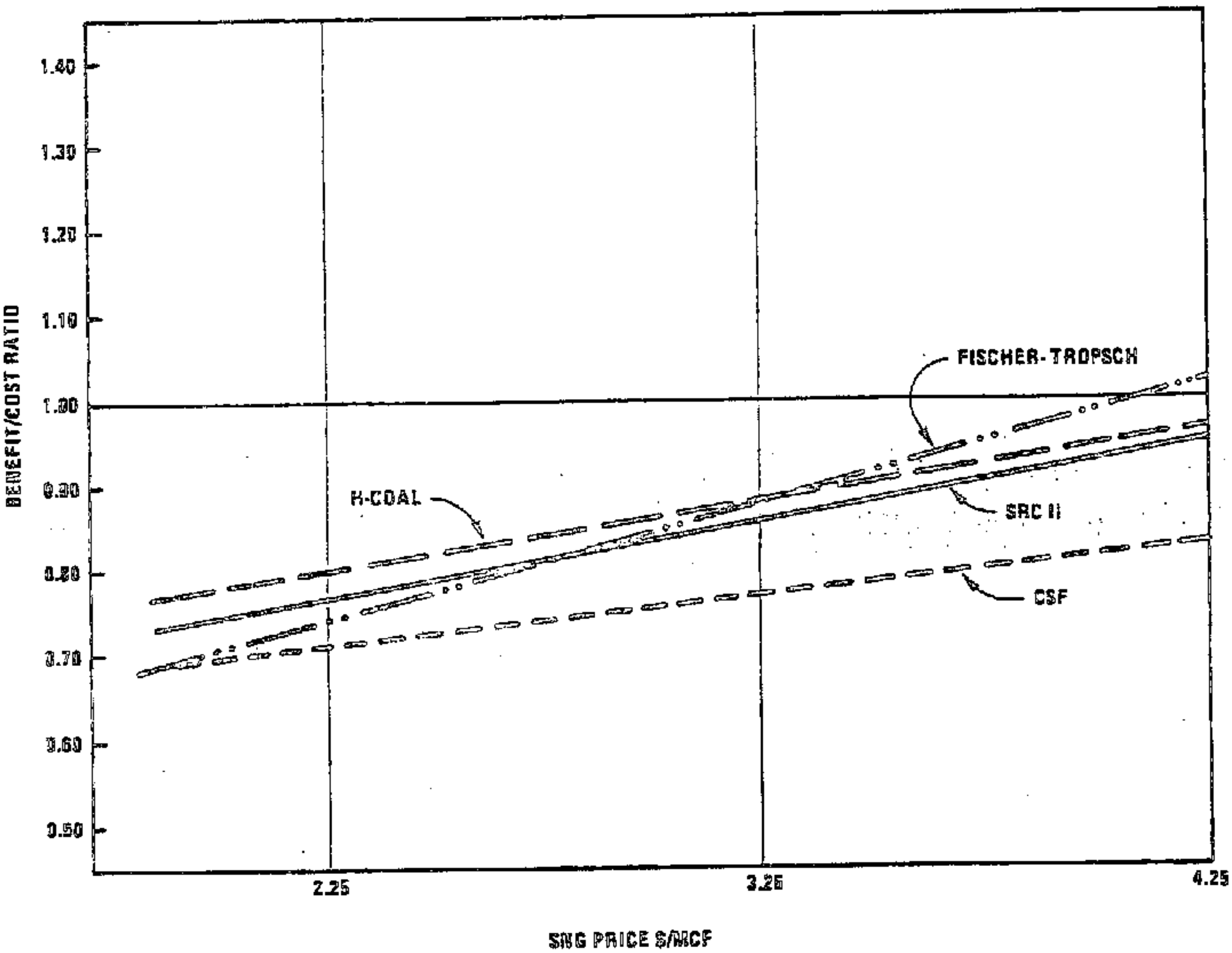

Figure 7-1 - Benefit/Cost Ratio Sensitivity to SNG Market Value

SECTION 8
DISCUSSION

SECTION 8

DISCUSSION

8.1 INTRODUCTION

The Section 7 economic comparison indicates that, for the process configurations, product compositions and economic assessment procedures used, the SRC II based technology offers the potential for lower fixed capital investments (see Table 7-2) and lower RPSP (see Table 7-5). The group of high potential processes show the following ranking in order of increasing capital cost:

1. SRC II based
2. H-Coal based
3. CSF based
4. Fischer-Tropsch based

When a benefit/cost (B/C) ratio index is applied, SRC II based, H-Coal based, and Fischer-Tropsch based processes show similar B/C's, with CSF indicating a lower B/C. Since the B/C ratio is defined as:

$$B/C = \frac{\text{Possible Annual Product Revenue}}{\text{Required Annual Revenue @ 12\% DCF on Equity,}}$$

The comparison of B/C and RPSP confirm Table 7-7 information that the H-Coal and Fischer-Tropsch configurations used in this study produce higher potential valued product slates than the SRC II based configuration.

The Fischer-Tropsch products differ from those produced by SRC II and H-Coal in that they have nil sulfur, nitrogen, and particulate contents. They also tend to be higher in aliphatic rather than aromatic in composition and would therefore have potential marketability as petrochemical feedstocks.

To summarize, the Fischèr-Tropsch products appear to have certain advantages relative to those produced in the hydroliquefaction processes (SRC II and H-Coal) with regard to environmental acceptability and potential value to the petrochemical industry.

Further suggestions for interpretation of the Section 7 comparative economics are discussed below and additional analyses presented.

The comparative economics developed in this study represent the results of a limited effort analysis. During the course of this limited effort, the characteristics of some 33 coal liquefaction processes were examined and four were selected for more detailed comparisons. Because adequate detail was not available for the Exxon Donor Solvent (EDS) process from DOE at the start of the study, DOE agreed that it would be excluded. Similar future studies should include the EDS, as well as the Mobil-M process.

In retrospect, the question of whether significant additional work (manhours) would seriously alter the results was briefly examined. To do this, more comprehensive conceptual design/economic evaluations by major contractors for SRC II based, H-Coal based, CSF based, and Fischer-Tropsch based process plants were reviewed, their results were compiled and analyzed, and the results are summarized later in this report section.

Another question retrospectively evaluated was the effect of differences in product slate on the comparative economics. A first approach to this analysis was a comparison of the hydrogen-to-carbon (H/C) ratio with fixed capital investment and required product selling price. The rationale behind this was that liquefaction involves the addition of hydrogen to coal which has a carbon hydrogen composition of approximately $CH_{0.8}$. Product aromatics will have a C:H composition such as CH, while aliphatics will appraoch CH_2 and SNG is CH_4. As more hydrogen is added to the coal, the products tend to be "more liquid," have lower sulfur and nitrogen contents, and tend to have a higher market value. The question of whether product H/C ratios might provide some indicator of the differences in economics to be expected between process plants which produce differing product slates was therefore briefly examined and the results are summarized below.

8.2 SUMMARY: MAJOR CONTRACTORS' CONCEPTUAL DESIGN/ECONOMIC EVALUATION RESULTS

The objective of this brief survey was to determine if similar economic comparison conclusions might have been drawn from inspection of the results contained in conceptual design/economic evaluation reports which used significantly more effort (manhours). To do this, reports for SRC II (Oil/Gas),[6] H-Coal),[12] CSF,[14] and Fischer-Tropsch[5] plants were reviewed. Similar comprehensive design reports were not available to us for the M-Gasoline or EDS processes. For the purpose of this comparison, captive coal mines and coal preparation costs were deleted from the reference report estimates. Also, the capacity of each plant was adjusted to 670 billion Btu/day of products (the Oil/Gas plant output which was the higher of the group) and the estimates escalated to first quarter 1978 dollars. No adjustments were made to process configurations or efficiencies.

The product slates for the four processes, expressed as percent of total fuels produced, on a Btu basis, are shown in Table 8-1. The results indicate that product slates vary widely making valid comparisons difficult. Note that the CSF process produces a very high percentage of gasoline (by extensive hydrocracking of heavy liquids at a high capital cost). On the other hand, the H-Coal process included very little upgrading; further, while gas is made by the H-Coal process none is shown as product indicating a designers option to consume this product to satisfy plant fuel requirements.

The fixed capital investment ratios are shown in Table 8-2; for comparison, the ratios developed in this study and presented in Table 7-2 are also presented. Only limited conclusions can be safely drawn from this comparison. These conclusions appear to be that when a given contractor compared several processes, the processes arrayed themselves in the same FCI ranking as developed in this study. To illustrate, the SRC II based and Fischer-Tropsch based conceptual designs/economic evaluations were developed by the same contractor, as were the H-Coal based and CSF based.

To properly compare processes where the designs/economic evaluations were developed by different contractors would require adjustments to factors such as thermal efficiency, and others.

To summarize, review of major contractors' conceptual designs/economic evaluations tends to corroborate the FCI rankings developed in this study. Conversely, comprehensive designs/economic evaluations which contradict these rankings are not known to exist at this time.

8.3 EFFECT OF PRODUCT COMPOSITION ON ECONOMICS

An objective of any comparison of process potential is to compare the economics for production of identical product compositions. Pragmatically, for a limited effort study such as reported here, this objective can be approached but not achieved. As an alternate, it would be valuable to define, in a simple manner, the economic impact of differing product compositions. The availability of such a correlation would assist in making meaningful comparisons between processes which produce different products. A brief start was made at the end of this study to better understand the relationship between product composition and economics.

A first approach was to investigate the relationship between the H/C ratio (weight basis), FCI ratio, and RPSP ratio. The incentive to look at this simple ratio is that as it increases, plant complexity increases, heteroatom content (S,N) decreases, and the products tend to be more "liquid."

To supplement the information from the high potential processes from this study, a brief arbitrary assessment of procedure and possible economics for production of SNG, using Fischer-Tropsch based technology, and 95% H_2 technology,[5] was developed. This second-order supplementary information is included as Appendix C.

H/C ratios and FCIs for plants to produce 600 billion Btu of fuels per day are shown in Table 8-3 and Figure 8-1. For SRC II based, H-Coal based, and CSF based, the H/C ratio increases in the same ranking as the

FCI ratio. Also shown in Figure 8-2 are H/C and FCI ratios for a modified SRC plant in which incremental hydrotreating capacity is added;[20] while the economic assessment bases differed from those used in this study, these independent predictions also show the same trend.

Figure 8-3 presents relative RPSP as a function of product H/C ratio. Here again a trend consistent with the prior rankings of the hydroliquefaction processes SRC II based, H-Coal based, and CSF based is evident.

With some judgment, the results indicate a different relationship for indirect liquefaction processes such as Fischer-Tropsch and SNG. It appears that the cost of complete gasification of the coal to produce syngas dominates the economics and the relative fixed capital investments are similar for SNG and Fischer-Tropsch.

For approximate comparative purposes, Figure 8-4, a least squares fit from plotted data, indicates product market value range as a function of H/C ratio. Here again, an upward trend of market value appears as the H/C ratio increases. It is of interest that a selling price for SNG consistent with the other fuels considered would be $3.75 per million Btu, a value intermediate between the base and high values used in the Benefit/Cost ratio comparison.

In summary, Figures 8-1 and 8-2 indicate that production of products with increasing hydrogen contents, plus the companion changes in sulfur content and product composition, can be expected to be accomplished at higher costs. These trend results, certainly not highly quantitative at this stage of development, highlight the need to compare process capabilities using equal product compositions. It also begs the question whether there are significant differences between major process contenders if they produce the same products. The answer to this question should recognize that the primary liquefaction facilities may represent approximately 25% of the fixed capital investment with the other 75% consisting of coal preparation, product recovery, and product refining. The trends illustrated in Figures 8-1 and 8-2 are considered significant in any comparison of liquefaction technologies and can be used as a guide to approximate economic impact of differing product slates for the appropriate process type.

Table 8-1 - Summary of Product Slates from Reference[5,6,12,14] Conceptual Designs

Product (% of Total Fuels, Btu Basis)	Process			
	Oil/Gas[6] (SRC II)	H-Coal[12]	CSF[14]	Fischer-[5] Tropsch
SNG	26.0	a	17.0	53.0
LPG	6.0		15.0	3.0
Gasoline			70.0	
Naphtha	8.0	38.0		19.0
Diesel Fuel				17.0
Heavy Fuel Oil				6.0
Syncrude		62.0		
Residual Fuel Oil	60.0			
Oxygenates				2.0
Total	100.0	100.0	100.0	100.0

[a]SNG is produced but is consumed in process as fuel.

Table 8-2 - Fixed Capital Investment Ratios
from Reference [5,6,12,14] Conceptual Designs
(Basis: 670 Billion Btu Products/Day)

Item	Process			
	Oil/Gas[6] (SRC-II)	H-Coal[12]	CSF[14]	Fischer-Tropsch[5]
FCI ratio from reference reports, 670 billion Btu/day	1.0	1.7	1.9	1.6
FCI ratio, this study, Table 7-2	1.0	1.2	1.4	1.7

Table 8-3 - Plant Product H/C and FCI Ratios

Process	H/C	Fixed Capital Investment
SRC II based	0.128	1.0
H-Coal based	0.150	1.2
CSF based	0.162	1.4
F-T based	0.284	1.7
SNG (F-T based)	0.323	1.7
H_2	4.29	1.4

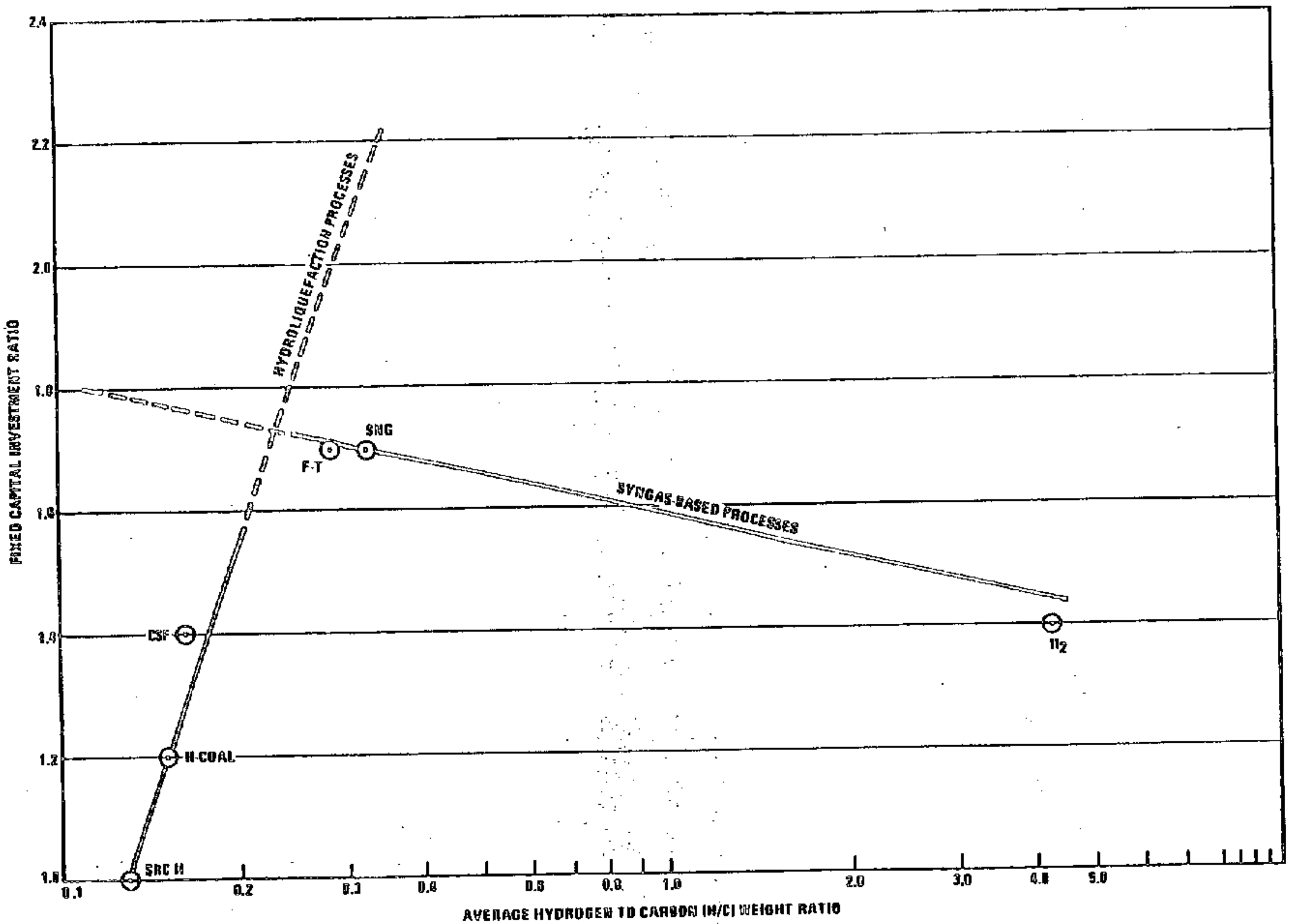

Figure 8-1 - Fixed Capital Investment Ratio
Vs. Average Hydrogen To Carbon Weight Ratio

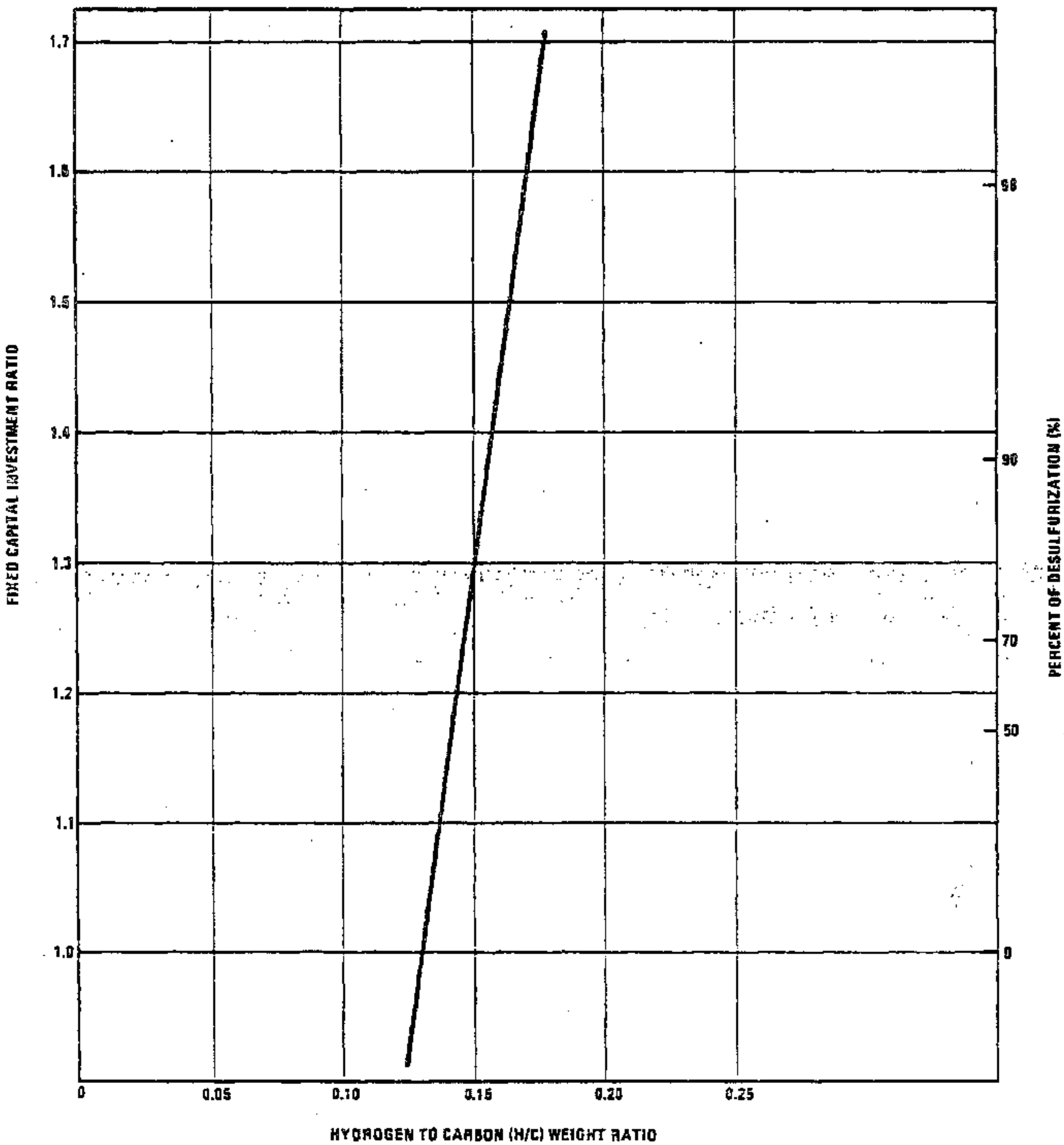

Figure 8-2 - Fixed Capital Investment Ratio and Oil/Gas Desulfurization
Vs. Oil/Gas Products Hydrogen To Carbon Weight Ratio

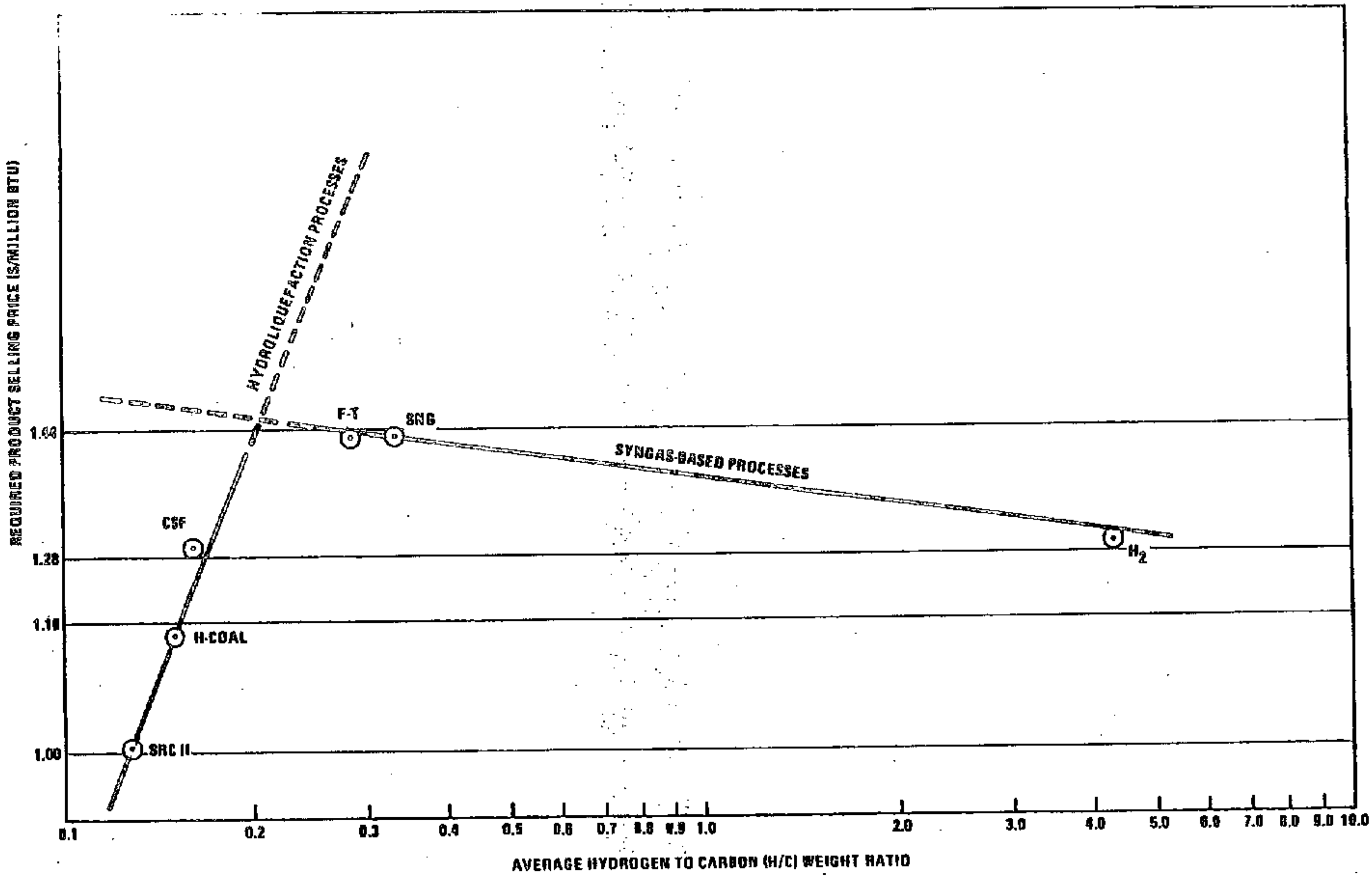

Figure 8-3 - Required Product Selling Price
Vs. Average Hydrogen to Carbon Weight Ratio

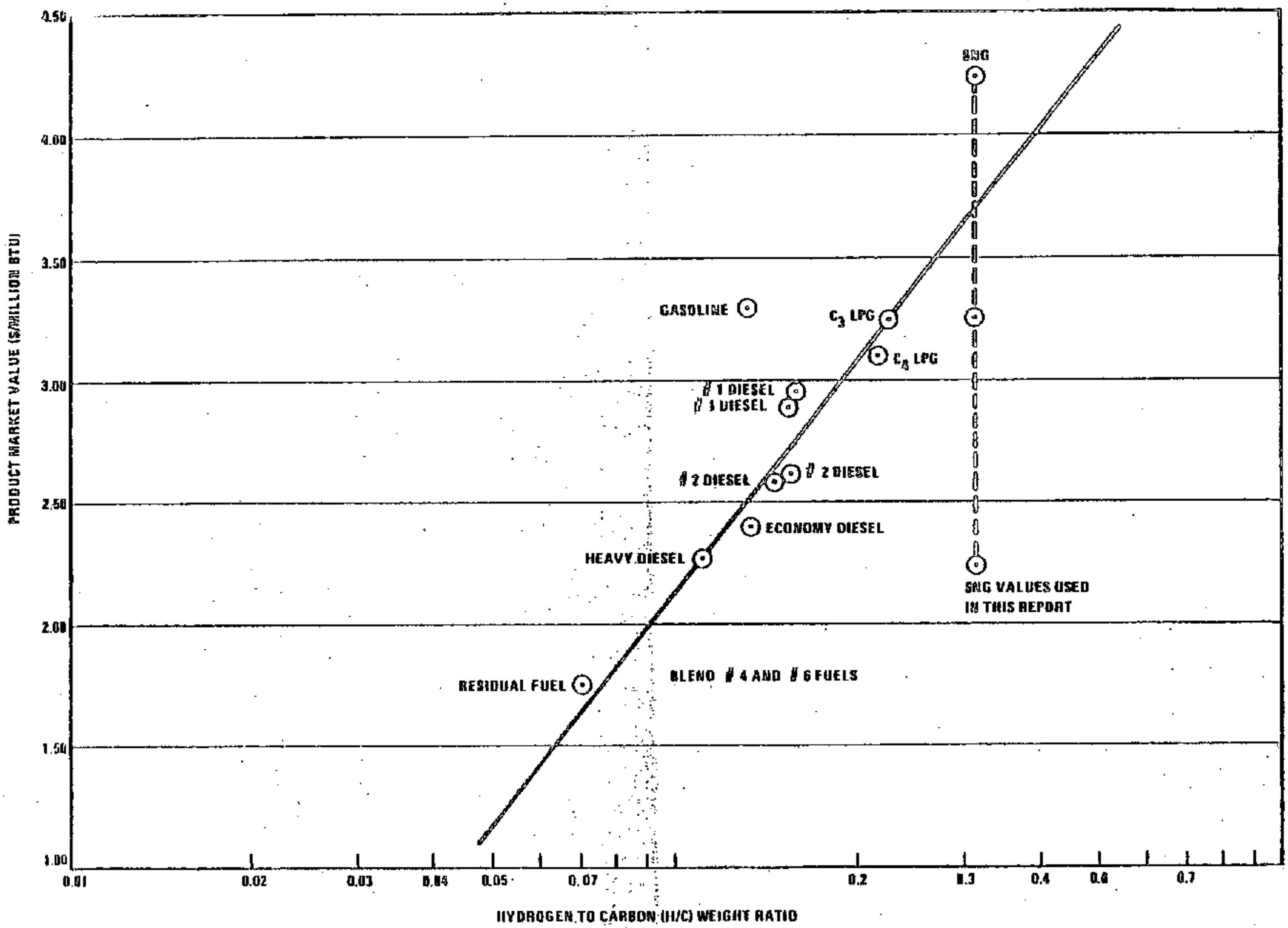

Figure 8-4 - Product Market Value
Vs. Hydrogen to Carbon Weight Ratio