OIL SHALE LIQUIDS COST

($1980)

	Per Barrel	Per Million BTU
Retorted Shale Oil	**$48.20**	$ 8.31
Upgrading	10.00	1.72
	$58.20	$10.03

These compare favorably with upgraded direct liquefaction production in the 'syncrude' class as shown below:

SYNCRUDE PRODUCTION COSTS

($1980)

	Per Barrel	Per Million BTU
Shale Oil	$58.20	$10.02
Direct Coal Liquids	21.12	18.5%
Shale Oil Advantage	12%	9%

The shale oil has about a 21%-cost advantage as a refinery feed-Stock. This is reduced to less then a 20% cost advantage on a heating value basis. However heating values are not the principal criterion to be applied to refinery feedstocks - quite the opposite - the lighter crude demands a premium. In certain instances the coal liquid with higher aromatic content will be preferred, at other refineries the shale oil, with a higher hydrogen content, and a greater yield of distillate product will be sought.

Exhibit 4-15 illustrates how the process of upgrading shifts the cost of oil shale and coal based synthetic crudes upward by $1.75 - 2.50 per barrel.

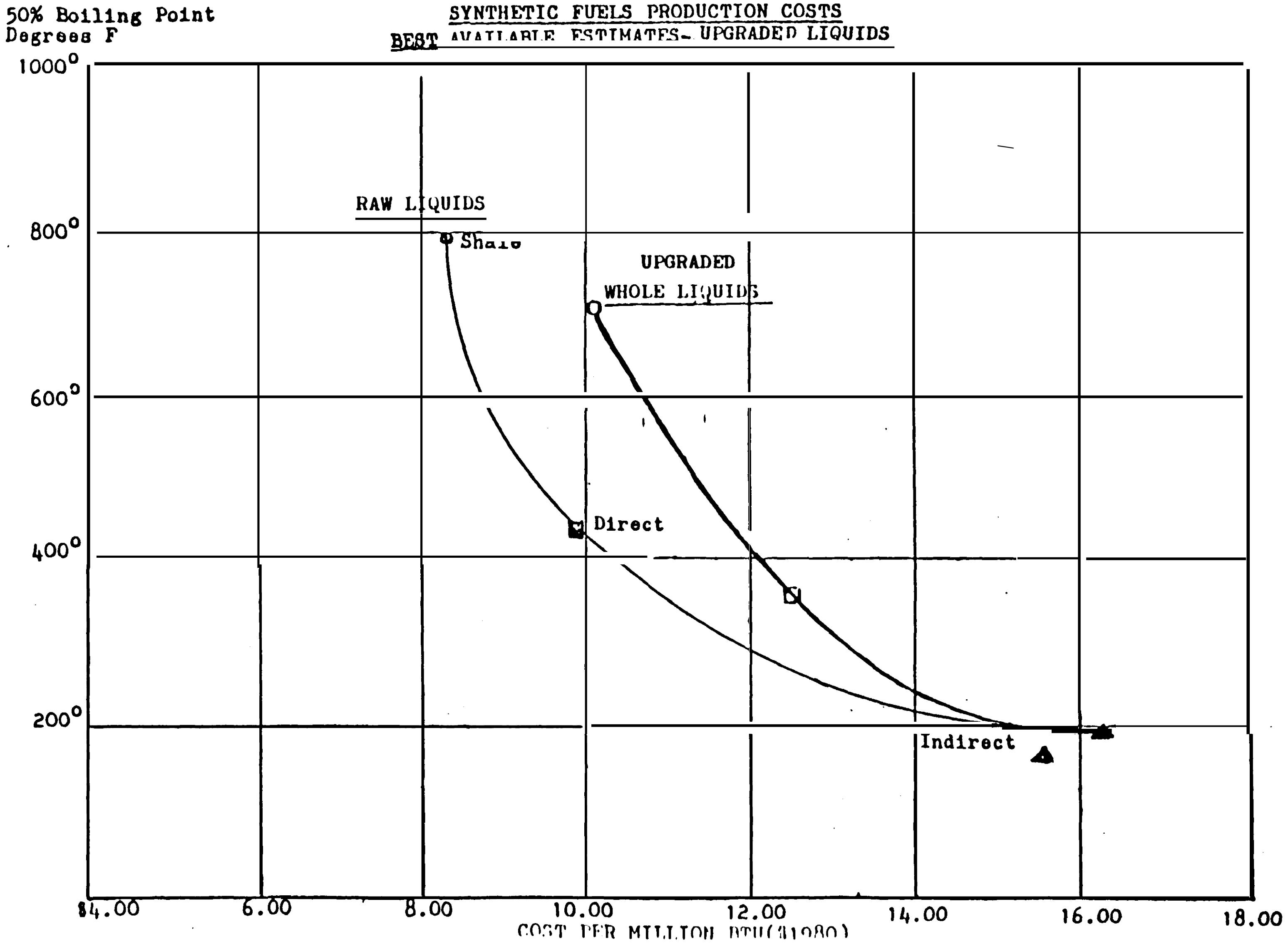
4.6 REFINING SYNTHETIC LIQUIDS

The direct liquefaction and oil shale synfuels have to be further upgraded to end-use product quality in order to be comparable with indirect liquid products such as methanol from coal or gasoline from methanol (from coal). In a wider sense, this is also desirable in order to achieve comparability with synthetic natural gas (SNG) which can be used for a wide range of end use applications in its 'raw' manufactured state.

The indirect processes produce refinery output (or intermediate) grade products, without the need for the "refining" of crude liquids. In order to compare direct liquids and shale liquids with indirect process liquids, we must bring the former

EXHIBIT 4-15

SYNTHETIC FUELS PRODUCTION COSTS
BEST AVAILABLE ESTIMATES- UPGRADED LIQUIDS



SOURCE: E. J. Bentz & Associates, Springfield, Virginia

into a state that is comparable. This requires the refining of the synthetic liquids to finished fuels.

Refining of shale oils and coal liquids will vary in cost depending upon the size, location and degree of integration of the refinery complex. We will assume that this is not done in an existing refinery (perhaps modified to better handle these feedstocks) , but is performed at a new refinery integrated at the retort or conversion plant site. Such a refinery is under-scale (50,000 bbl/day) and remote from chemical complexes that might make better use of by-products and hence provide higher (by-product) credits or other similar economic benefits.

The costs of upgrading the raw coal and shale liquids to high grade (transportation) fuels is shown below:

REFINERY COSTS FOR SYNTHETIC (RAW) LIQUIDS

($1980)

	Cost Per Barrel	Cost Per Million BTU
Shale Oil (Hydrotreat & Hydrocrack)	$18.50	$3.19
Coal Liquids (Hydrotreat)	$18.29	$4.02

The costs of refining synthetic liquids cannot truly be determined without specifying the product slate produced. The costs of refining a particular feedstock can vary depending upon the product cuts sought. The basis used above is not strictly comparable between the processes. It tends to slant the refinery approach to the type of slate that is favored by the feedstock - Light distillates in the case of shale oil, and gasolines and distillates in the case of coal liquids.

Exhibit 4-16 illustrates the potential variation.

These costs can be seen to vary dramatically if different product slates are sought. If the highest grade transportation fuels are maximized, to provide the highest degree of comparability with indirect liquids. The costs are as follows:

REFINERY SYNTHETIC UNITS TO 100% TRANSPORTATION FUEL

($ 1980)

	Shale		Coal	
	$/BBL	$/MM BTU	$/BBL	$/MM BTU
Raw Liquid	$48.20	$ 8.31	$66.47	$ 9.79
Upgrading	18.50	N.A.	18.28	N.A.
Total	$66.70	- $11.50	$84.75	- $14.61
Average Heat Content\ BBL	5.8 Million BTU		5.8 Million BTU	

EXHIBIT 4-16

PROCESS AND SLATE

(1980 $)

Feedstock	Hydrotreat & Hydrocrack	Severe Hydrotreat	Moderate Hydrotreat
Coal Liquids*			
Product	Motor Gasoline	Motor Gasoline Plus Jet Fuel	Motor Gasoline Plus #2 Fuel Oil
Slate	(100%)	(1/3 - 2/3)	(1/3 - 2/3)
Cost	$20.70	$18.29	$12.55
Shale Liquids	Hydrotreat & Hydrocrack	Hydrotreat-FCC	Coking Hydrotreat
	3/4 - 1/4		(4/5 - 1/5)
Product Slate	Motor Gasoline Plus Jet Fuel	Jet Fuel Plus Motor Gasoline	Jet Fuel
Cost/BBL	$18.50	$17.00	$16.00

*SRC-II

SOURCE: E. J. Bentz & Associates

By comparison, indirect liquid (methanol to gasoline) costs are about $78.00 per barrel; approximately in the middle of this range. The cost per million BTU's is lower for shale and coal liquids, refined to a transportation slate consisting of gasoline and distillate fuels (jet fuel and diesel oil). If direct liquids are refined to a 100% gasoline slate the costs would increase to $87.17 per barrel or above $19.00 per million BTU's.

Exhibit 4-17 graphically displays the finished fuels in a framework which relates the product quality to the finished fuel cost.

Exhibit 4-18 calculates the total cost of refining coal liquids. A 50,000 barrel per day refinery for coal liquids would cost between $420 million and $690 million. The lower case represents a moderate hydrotreatment plant producing #2 fuel oil and gasoline, the upper case represents a hydrotreatment and hydrocracking plant that produces 100% gasoline.

Instead of using other indirect measures of product value,[18] we can use a cost based scale. The lighter fractions cost more to produce from both coal and shale, whether by direct or indirect means. By-product credits do not have to be assigned to determine the cost of a single cut liquid. Upgrading plant has been assigned to individual fractions so that the full cost of the beneficiated product cut is known. The costs of fully refining the product are developed incrementally by determining the cost of creating a 100% gasoline yield, and two subsequently lower grade mixtures.

The alternate product slate refinery costs of Exhibit 4-18 can be used to develop a measurement of the direct costs of products in a multi-product refinery run. The principal cost differences result from the increased capital (per unit of product yielded) and the increased consumption of hydrogen associated with higher grade product slates.

If we take the per barrel cost of producing a 100% gasoline slate. and assign it to the gasoline fraction of a mixed slate as the appropriate cost of that portion of the output, the remainder of the total cost divided by the number of barrels of the other product (jet fuel or #2 fuel oil) will give us the unit cost of the "secondary product".

Exhibit 4-19 shows this costing procedure for the slates presented for direct liquids refining in Exhibit 4-17.

By using this method, we are not artificially lowering the cost of gasoline production by assuming a market equilibrium price

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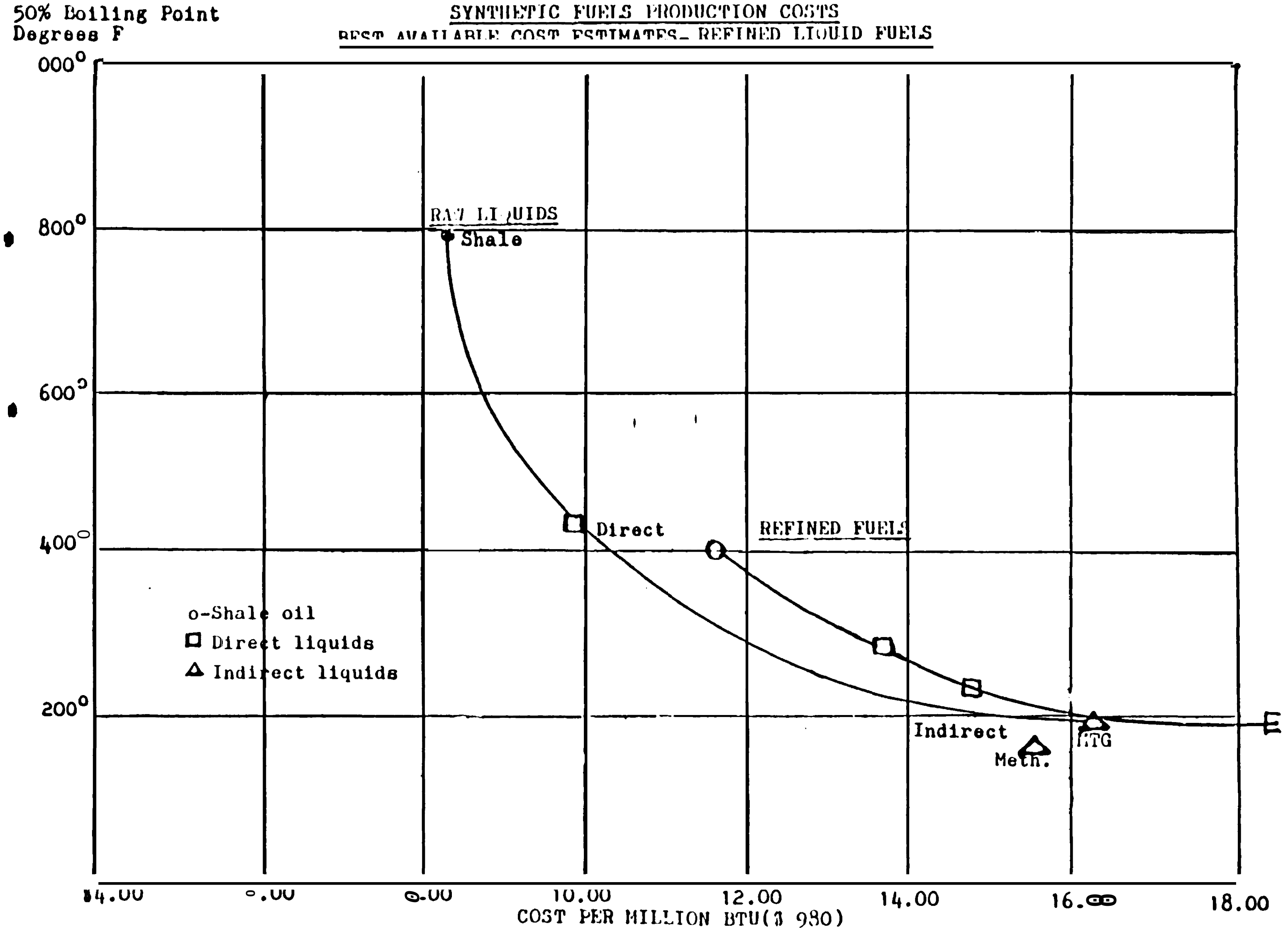
[18] Product value ratios are commonly used. They are of absolutely no meaning in a long-term and discontinuous supply context. The use of such ratios is a major violation of the most elementary laws or principles of economics as a measure of utility.

EXHIBIT 4-17

SYNTHETIC FUELS PRODUCTION COSTS
BEST AVAILABLE COST ESTIMATES- REFINED LIQUID FUELS



SOURCE: E. J. Bentz & Associates, Springfield, Virginia

EXHIBIT 4-18

DIRECT LIQUIDS (SRC-II) REFINING

(50,000 BBL/Day) 1980 $ per BBL.

$/BBL	Motor Gasoline (Hydrotreat Plus Hydrocrack)		Motor Gasoline Plus Jet Fuel (Severe Hydrotreating)		Motor Gasoline Plus #2 Oil (Moderate Hydrotreat)	
Operating Labor	.244		.183		.183	
Maintenance	.791		.669		.487	
G&A	.852	1.887	.670	1.522	.487	1.157
Fuel	.183		.304		.122	
Utilities	.183		.122		.122	
Cat. & Chem.	.304		.365		.244	
Hydrogen	5.540	6.210	5.750	6.541	3.230	3.718
Capital Recovery @ 30%/Yr.		12.603		10.228		7.67
		$20.70		$18.291		$12.545

SOURCE: E. J. Bentz & Associates

EXHIBIT 4-19

SRC II REFINED TO PRODUCT COSTS

		Barrels/Day		Cost/BBL*	Total Daily Cost
CASE I	Motor Gasoline	50,000	@	$87.17	$4,358,500
CASE II	Motor Gasoline	15,395	@	87.17	1,341,982
	Jet Fuel	34,605	@	(83.69 **	(2,896,018)**
	Total	50,000	@	$84.76	$4,238,000
CASE III	Motor Gasoline	16,995	@	$87.17	$1,481,454
	#2 Oil	33,005	@	(74.74)**	(2,466,796)**
	Total	50,000	@	$78.965	$3,948,250

Product Costs

Motor Gasoline = $87.17/bbl (4.95) $17.61/MM BTU
Jet Fuel = $83.69/bbl (5.67) $14.36/MM BTU
#2 Oil = $74.74/bbl (5.825) $12.83/MM BTU

*Cost from 4-17 plus 4-9.

**Values in parenthesis inferred from weighted average value of motor gasoline and total product.

SOURCE: E. J. Bentz & Associates

for a lower grade (by) product. The method used is entirely an assignment of marginal cost to products. It would be more desirable to operate in a reverse manner, i.e., from the lowest product, assigning incremental costs to the higher product on a marginal basis. We, unfortunately, do not have a process estimate for a single slate of the lowest value product. The distillation range of all products is too broad to produce such an artificiality. Therefore we have begun with the marginal gasoline cost and assigned it as a by-product price to the lower value (mixed) slates, permitting us to infer the marginal cost of the lower grade products.

The results of this cost analysis are related to the costs of indirect liquefaction end products and shale products on Exhibit 4-20. The cost series increase as average distillation point is lowered. The average distillation point of most useful transportation fuels lies between 180° - 400 F, with the majority of the compounds contained lying within this range.

There is a persistence of the earlier noted relationship between product quality (as measured by average boiling point) and production costs of finished products. The relationship shows less than unitary cost increases per barrel, all greater then unitary cost increases per million BTU. The latter case is due to the generally lower heating value of the premier fuels that have increased hydrogen content. The increases in cost are about 7 1/2cents per barrel of liquids for every degree farenheit that the boiling range is lowered.

Exhibit 4-21 is a flow sheet of a process (examined by Chevron Research) for hydrotreating and hydrocracking of direct coal liquid (SRC-II) whole oil to produce 100% motor gasoline product. This is the first case on Exhibit 4-16. Exhibits 4-22 and 4-23 illustrate the refining process used to upgrade the whole liquid to ‘ gasoline and jet fuel by severe hydrotreating alone, and to a lower quality slate of gasoline and heating oil created by less severe hydrotreating of direct (SRC-II) liquids.

The latter case is more comparable to an upgrading process.

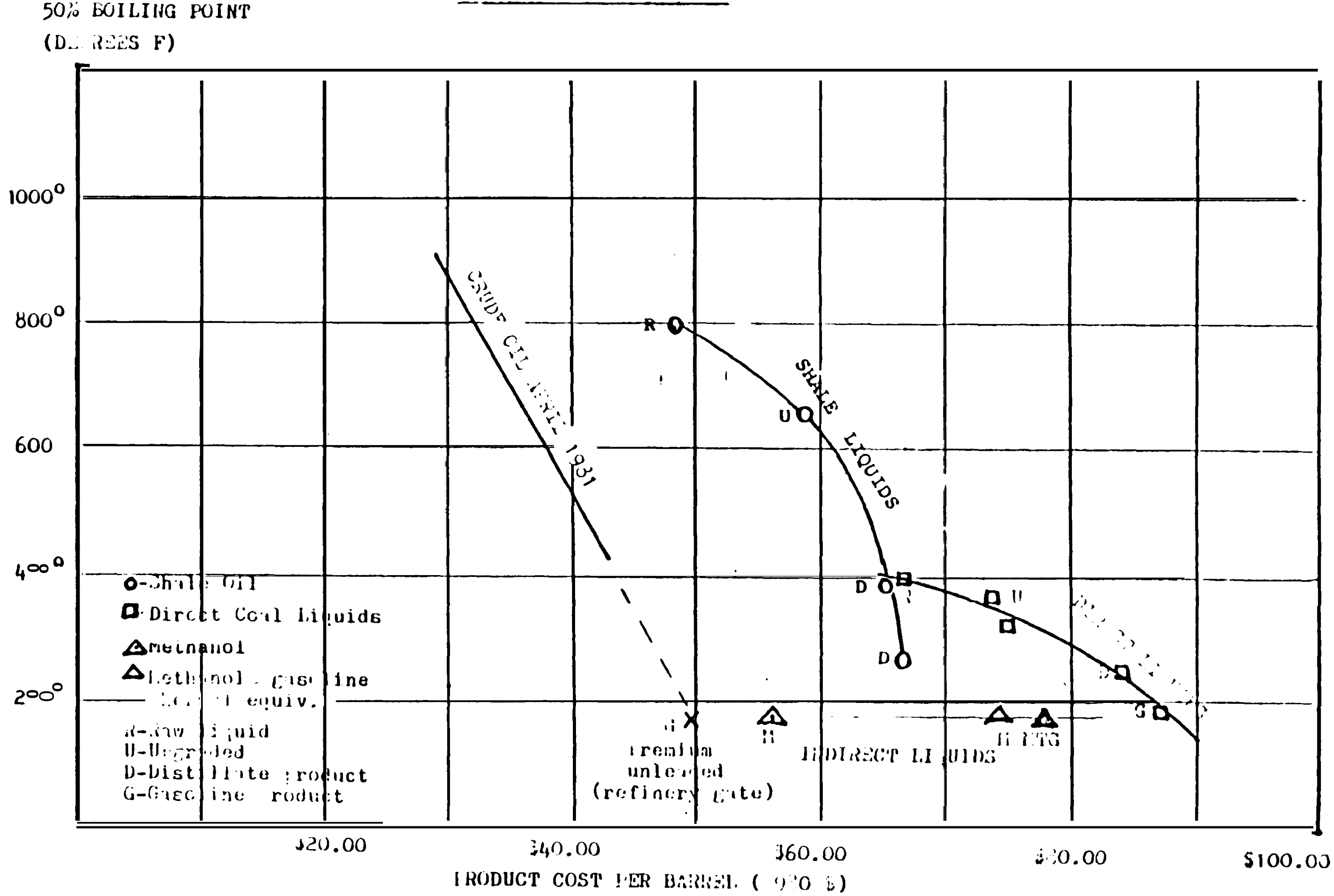
4.7 TRANSPORTATION AND OTHER INFRASTRUCTURE COSTS (Reference 41)

Although we have differentiated between coal liquid’s plant site upgrading facilities and finished product refineries, we have really not selected the site for refining. The upgrading must in most cases be done at the site of the coal liquids plant. The degree of upgrading we have embraced (Exhibit 4-15) is sufficient to permit the fuels to be used in as high a use as a combustion turbine, or transported without creating contamination or incompatible sediments.

Transportation costs are directly related to the distance involved, and indirectly related to the quantity moved or flow rate.

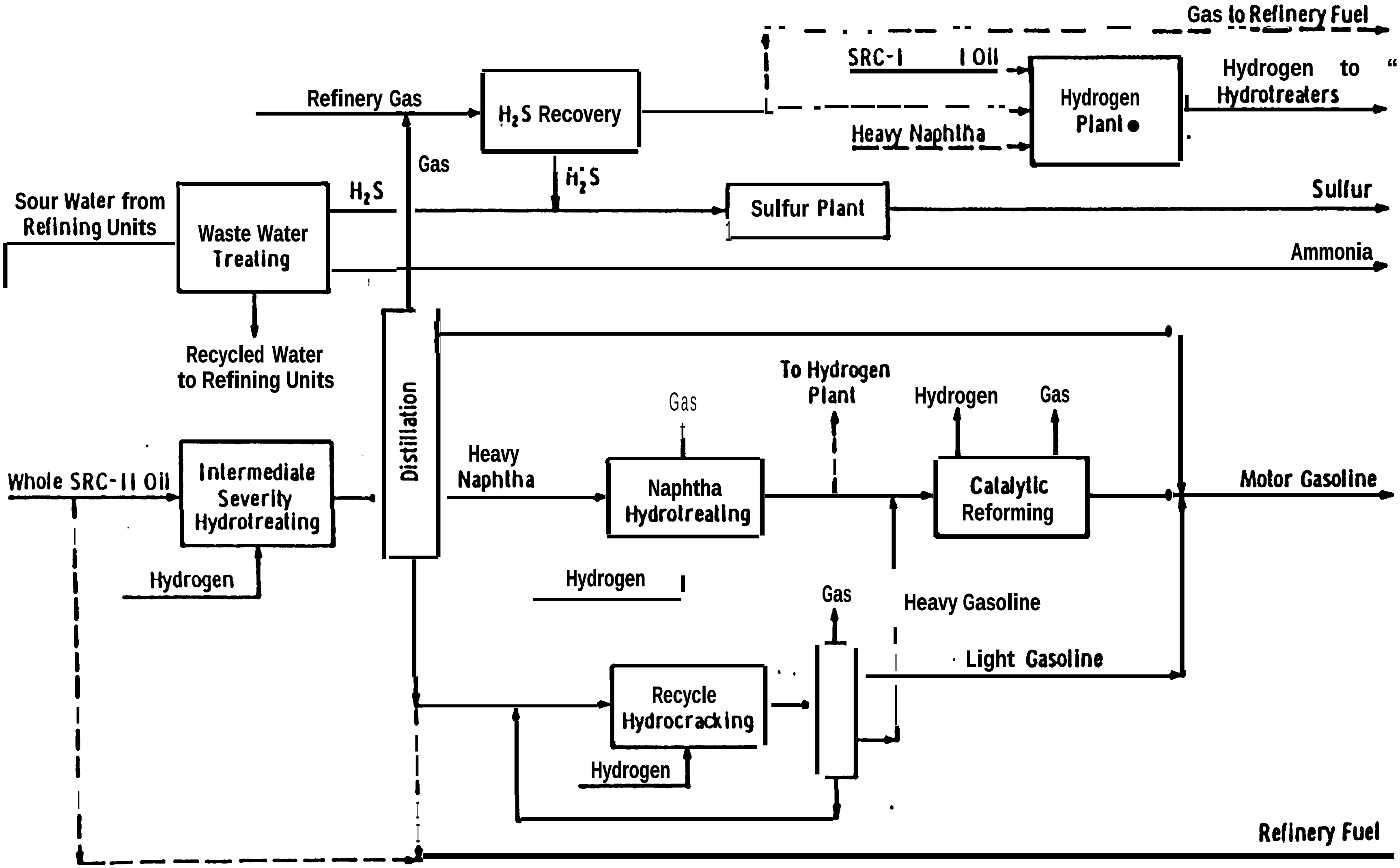
EXHIBIT 4-20

SYNTHETIC FUEL LIQUIDS



SOURCE: E. J. Bentz & Associates, Springfield, Virginia

EXHIBIT 4-21: SCHEMATIC FLOW DIAGRAM REFINING OF SRC-11 OIL BY HYDROTREATING AND HYDROCRACKING - CASE I

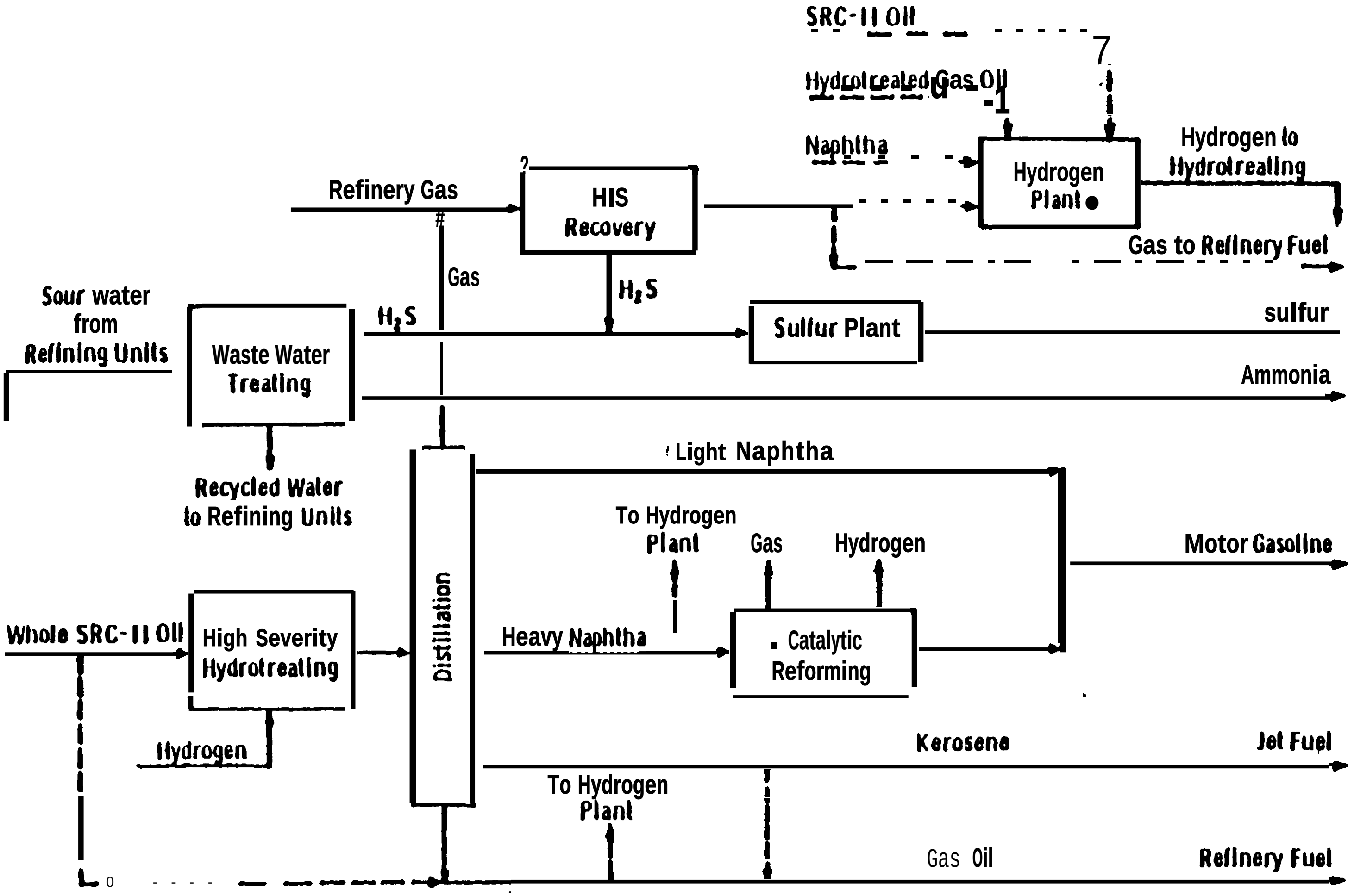


* Steam reforming feeding gas and anphtha in Cases 4A, 4B, and 4D.
Partial oxidation feeding SRC-II oil in Case 4C.

SOURCE : Department of Energy

EXHIBIT 4-22:

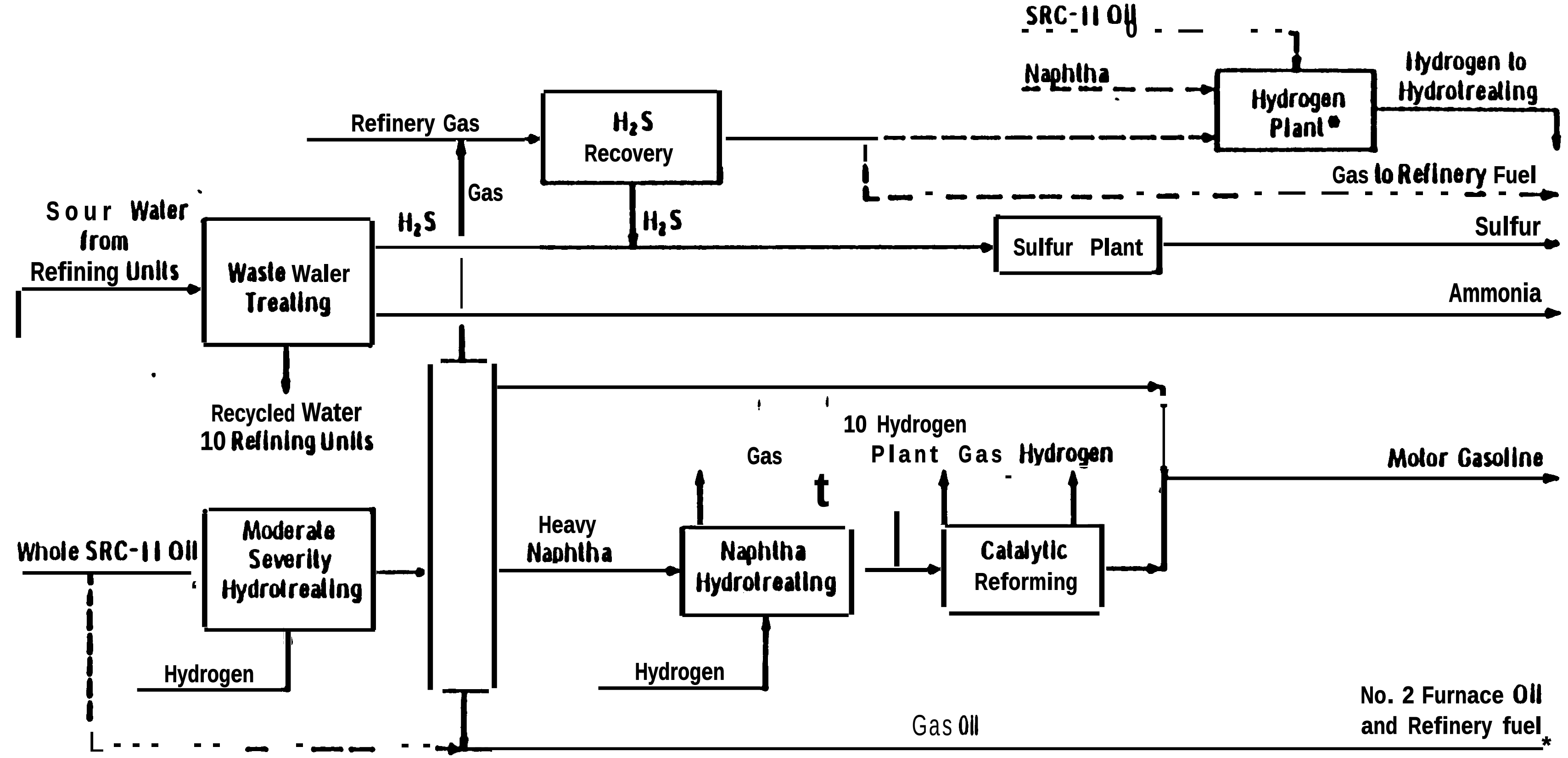
SCHEMATIC FLOW DIAGRAM
REFINING OF SRC-II OIL BY
HIGH SEVERITY HYDROTREATING - CASE II



● Steam reforming feeding gas and naphtha in Cases IA, IB, and ID
Partial oxidation feeding gas oil and SRC-II oil in Case IC.

SOURCE : Department of Energy

EXHIBIT 4-23: SIMPLIFIED FLOW DIAGRAM REFINING OF SRC-II OIL BY MODERATE SEVERITY HYDROTREATING - CASE III



* Steam reforming feeding gas and naphtha in Cases 5A, 5B, and SD.
Partial oxidation feeding SRC-II oil in Case SC.

SOURCE : Department of Energy

We cannot visualize any other form of transportation for these upgraded liquids, or for further refined products except by pipeline. The daily volume required to support a 6" or 8" pipeline is approximately the size of one or two 50,000 bbl/day plants. Considering the geographical concentration of coal and shale deposits it is not difficult to visualize a mining-conversion center adequate to support either:

- An upgraded liquids pipeline to a refining center

or

- A product pipeline to major pipeline junctions or product distribution terminals

The general location of all coal and shale resources is such that deep draft water transportation does not figure prominently in synfuels distribution patterns.

Without siting specific plants and conducting the refinery trade-offs - which would have to be done in context with both the balance of foreign and domestic petroleum supplies and the slate of (regional) demand for all liquids - we cannot develop very meaningful insights into either the operating (product) costs of transportation and distribution, or the capital requirements.

We will have to make some nominal assumptions and then establish unitary relationships. The future energy transportation patterns and infrastructure requirements are impossible to determine without a specific scenario. We shall briefly examine a *cases:

- Pipelining from Souther Illinois to Houston of syncrudes.
- Pipelining from Wyoming to St. Louis
- Pipelining from Western Colorado to L.A. of shale oil.

Southern Illinois to Houston	
Raw Liquids (upgraded)	33c/MM BTU
Western Colorado to L.A.	
Shale Liquids	40$/MM BTU
Wyomina to St. Louis	
Raw Liquids m ′ * ′	30 $/MN! BTU
Methanol	68c/MM BTU
MTG - Gasoline	37$/MM BTU

The additional capital investment required for synthetic fuel transportation is highly speculative to a greater degree. There is a great deal of existing product and crude liquid pipeline as well as gas pipeline in place, that can equally serve the synthetic fuels industry. In all cases the pipelines are connected to either markets or distribution terminals at the delivery end. In most cases, the input end is originally either at a major refinery (and production) location or at a port location. The refinery connection argues for upgrading of liquids (coal and shale) at mine mouth conversion plant locations, and transportation to the existing refinery districts for product finishing. Such a general pattern would involve the construction of a minimum number of new "crude" synfuel pipelines from coal fields to refining districts.

We assume that the ultimate conditions would lead to the construction of several large diameter pipelines in such a pattern.

Methanol, which does not require refining, obviously will move in different patterns from coal field to the major terminals and markets.

Pipelines of that size (10-12") would cost an average of $100,000 per mile, considering material, labor, and right of way and other expenses. Terrain would influence the cost, generally increasing construction costs but reducing right of way costs in some cases by an equivalent amount. 20" or greater diameter pipelines would cost $250,000/mile.

A total construction budget of 50,000 miles of new pipeline of 12" diameter to 20" diameter would cost between $5 billion and $12 billion.

4.8 ADDENDUM TO CHAPTER 4: BASIS FOR COST ASSUMPTIONS

1) Basic Conversion Plant (ESCOE)

- **Capital Costs**

Year: Mid (June-July) 1979 dollars
Scale: 25,000 tons of coal input
Base Plant to installed battery limits: 1.63
Contingency: 10%
Scaling exponential rule: $C_2 = G$
C_1

λ = .65 for vessel size
λ = .9 with trains

Outlay of Capital: instantaneous plant

- **Revisions to Capital Assumptions in This Report**

Year: Mid 1980 (June-July)
Scale: 50,000 bbl/day liquids output
Plant to Battery Limits: 1.73
Contingency: 20%
Scaling: Linear
Outlay of Capital: Instantaneous plant

- **Operating costs**

Coal Feedstock: $30/ton (delivered)
Coal: Illinois #6
Catalysts and Chemicals and Operating Supplies: at cost for amounts proscribed by process designer’s material balance.

Labor Cost	#		Rate/Hr
Plant Operators	120		$ 10.00
Operating Supervisors	25		15.00
Maintenance Labor	150		12.00
Maintenance Labor Supervisors	30		16.00
Administration	30		11.00
Total	355	@	$11.79/hr avg.

Fringes @ 35%--changed to 40% = total labor rate of $16.50/hr

Maintenance Cost (Materials & Contracts)

3% of total plant capital cost

G & A

Local taxes and insurance, 5% capital cost changed to total G&A - 5% capital cost

Capital Charge Rate

ESCOE basis not used. 30% of capital used as recovery rate (as per guidance of OTA staff) .

On-Stream Rate

90%--328.5 days/year

2. Assumptions for Product Upgrading

- Capital

  Basis --Instantaneous Plant, mid-1980 dollars
  On-stream factor 90% 328.5 stream days.

- Hydrotreater

  capitalized for each separate product stream.

- Hydrogen Feedstock Plant Capital

  Not included, only cost feedstock "across the fence" from the plant complex.

- Hydrogen Reformer or manufacturing plant capital included

- Battery Limits

  Includes hydrotreaters, waste water treatment, sulphur plants (commercial grade)

- Contingency

  General -- 25%
  Battery Limits--15%
  Engineer---4% of investment capitalized
  Working Capital--45 days receivables; 30 day chemicals catalysts; 30 day feedstocks

- Operating costs

Hydrogen Feedstock: Syngas @ $6.74/mmbtu raw gas liquids @ $6=50/mmbtu includes recovery of production plant capital.

Hydrogen Pressure: 500 PSIG for SRC light (naptha) product --2000 PSIG all other cases.

Plant Size: 20,000 bbl/day upgraded to 50,000 bbl/day for each product cut

- Royalties

500 PSIG Hydrotreating	-o-
1500 PSIG Hydrotreating Fixed Bed	$30/bst feed
Sulphur plant	-o-
Waste Water	
Initial project	$75,000
First 5,000 units	$14.70\unit
Next 5000-25,000 units	$7.35/unit
Next 25,000 + units	$5.25/unit

- Sales Tax

5% of equipment cost

- Maintenance

4% of depreciated capital/year

- Operating Labor

$11.00/hr

- Labor Burden

45%

- Administrative and Support Labor

30% of operations and maintenance labor

- G & A

60% of operations and maintenance labor plus property-tax of 2-1/2% of plant investment

- Utilities

Fuel	$4/mmbut
Steam	$3.50/1000 lbs
Electricity	4c/kwh
Water (make-up)	40c/1000 gal

- Hydrogen Bleed was assumed to be:

  50 SCP/bbl @ 500 PSIG
  100 SCP/bbl @ 2000 PSIG

- By-product Credits

  Ammonia (anhydrous) $100/ton
  Hydrogen and Hydrocarbon off gasses (C_1-C_4)
  $4/mmbtu ($1. 30/MSCF)

3. Refining Cost Assumptions (Chevron Basis)

- 1980 costs: Instantaneous plant (first quarter adjusted to June/July)

- Mid-Continent Location

- Cost correlations based on actual experience of Standard Oil of California, 1960-1970s adjusted for:

  Lower field productivity
  Increased safety
  Improved efficiency and reliability
  Additional energy conservation
  Stricter environmental regulations

- 10% Contingency

- Utilities

  Water 30c/1000 gal
  Boiler fuel, coal or refinery fuel
  power 3$/kwh

- Maintenance

  2-1/2%/yr of both on-plant and off-plant facility investment

- G&A
  Property taxes @ 21/2% of both on-plant and off-plant/yr

- Labor

  Operating-- $110,000 per shift position/hr
  ($18.30/hr including fringes)
  Support Labor (Administrative, security, technician) 65% of Direct Labor

CHAPTER 5: SUPPLY DEPLOYMENT SCENARIOS FOR SYNTHETIC FUELS

CHAPTER 5 : SUPPLY DEPLOYMENT SCENARIOS FOR SYNTHETIC FUELS

5.1 Factors and Constraints Affecting Synfuel Development

In order for synthetic fuels to play a role in increasing domestic energy supplies, they must become available in sufficient quantities, at competitive prices, in a reasonable time frame. This is particularly true for transportation's needs for liquid fuels. With a relative lack of fuel switching capability, transportation more than other sectors (e.g., utility fuel switching to coal) must depend on increased conservation, expanded domestic crude production, and alternate liquid fuels.

The central driving forces that characterize the development of a synthetic fuel industry are (Reference No. 42):

(a) Depletion and cost escalation of conventional domestic energy supplies;

(b) Shortages of environmentally acceptable fuels;

(c) Constraints imposed on alternate energy systems;

(d) The presence of existing, easily modified fuel distribution systems;

(e) A seemingly chronic negative imbalance in foreign trade and payments accounts;

(f) National security; and

(g) Governmental incentives (such as those proposed under P.L. 96-126 and the National Energy Security Act) .

The central concerns are:

(a) Technological and economic factors

    . product costs/markets (interfuel competition)
    Status of technology and technological risk
    Financial risk
    Capital availability

(b) Environmental and social factors

    - Air quality
    - Water quality
    - Land reclamation
    - Social dislocation

(c) Availability of resources

- Energy resources
- Water resources
- Land/site availability
- Skilled work force

(d) National, State, and local policies, especially regulatory, taxation, and subsidy policies.

Key among the requirements that characterize these concerns are:

(a) Technological needs
(b) Significant lead times
(c) Relative costs

In Chapter 3, we have looked at the technological needs; and in Chapter 4 we have looked at the relative costs. In this chapter we will focus on the "staging" over time of these technologies, so that we can appreciate the necessary lead times. In doing so we will attempt to develop realistic "bottoms-up" assessments for each generic fuel class.[a] These"scenario# will be a 'business-as-usual" assessment, and a high "pushing-the-limit" assessment.[b] In developing these scenarios we have felt it crucial to build upon concrete actual data and engineering plans for each project class, rather than "top-down" estimates of aggregate growth.[c] We also felt it necessary, as explained in the introduction, to limit our supply deployment scenarios to the year 2000, which reflects the upper limit of sound engineering judgment and actual/proposed plans. Post 2000 considerations are more dictated by an assessment of economic forces and prospective product markets rather than supply constraints.[d] The supply constraining forces of the "transition" period (1980-2000) reflect industrial 'build-up" times and constraints, rather than product demand shifts.[e] Post 2000 considerations must consider demand shifts, end-use technology changes, and the introduction of other technologies (e.g., solar) .[F] This necessitates a macro-economic long-term forecast approach rather than a supply deployment scenario approach.[g]

Because of the significance of "transition" period[h] constraints in realizing deployment schedules, it is useful to discuss these constraints prior to our development of the scenarios. In the following section we will discuss the key constraints. Following this discussion, we will present the actual assessments developed and compare them with other assessments referenced in the literature.

5.2 Constraining Factors in the Transition Period: 1980-2000

The construction of one 50,000 barrel per day synthetic fuel facility is a massive effort requiring huge dollar, manpower, and material inputs plus the management skills to integrate all these inputs into a workable system. Constructing a major synfuels industry multiplies the problems, introduces added complexity, and increases the probability that constraints of varying degrees will impact the schedule, cost or feasibility of success.

Any Us. proposed synfuels construction program will have to compete for manpower and other resources with related construction demands from the oil and chemical fields. U.S. refineries are undertaking a major upgrading program to enable existing refineries to handle lower grade high sulfur crude and to increase efficiency in producing full product slates with less energy waste. Fluor Corporation is predicting that U.S. refineries will initiate $20 billion in construction programs in 1980, contrasted with a yearly average of only $2 billion in the late 1970s. (Reference No. 43) Proceeding with the Alaskan Natural Gas Pipeline could require $20 to $25 billion in new construction costs. Similarly, the chemical industry is modifying its petrochemical plants in recognition of dramatically higher feedstock costs. The situation is further compounded by gigantic increases in construction programs abroad. For example, Saudi Arabia appears intent on pursuing a five year $335 billion program of new refinery and petrochemical construction. These construction programs will use the same international construction companies, technical skills and equipment as will be required for U.S. liquid synfuels construction. (Reference No. 43).

The purpose of this section is to discuss the range of potential constraints to the development of a viable liquid (and gas) synthetic fuels industry in the U.S.

This discussion of constraints is organized into the following categories:

Equipment	availability-- supply constraints performance constraints
Critical Materials	
Manpower	technical laborforce construction laborforce
Coal Supply	
Water Supply	

- Environment, Health and Safety
    - standards and requirements
    - permits and licenses
- Siting
    - physical location
    - infrastructure problems
- Transportation
- Technology Uncertainties
- Financial/Capital Availability
- Economics
    - operating costs
    - product costs

Chapter 3 has already covered the technologies, and Chapter 4, the economics. Capital availability has not been discussed here in this report. Additional assumptions on monetary policy and macro-economic policy over the next 20 years will be needed to consider this topic.

5.2.1 Equipment Problems

Seven different types of equipment which might **cause** supply constraints have been identified as follows:

Availability - supply Constraints

1. Pumps: Demand for pumps in synfuels plants will be very large. However, for small pumps, less than 1000 hp, there should be an adequate supply since producers could expand to three shift operations and European and Japanese manufacturing is available (Reference No. 44)= Large reciprocating pumps would be in very short supply assuming that existing baseline demand persists. The synfuels industry could require between **50%** and 100% of current world production capacity (Reference No. 44).

2. Heat Exchangers: Demand is expected to exceed 25% of total domestic and foreign production capacity (Reference No.45). However, the industries' ability to increase capacity is reasonably good. The limiting factors would be availability of welders and of heat-treated metal plate from primary suppliers (Reference No. 44). Without firm orders, the heat exchanger manufacturers are reluctant to expand productive capacity.

3. Compressors and Turbines: Like heat exchangers, demand for compressors and turbines by synfuels plants could exceed 25% of existing production capacity (Reference No. 45). Traditionally, there is a two year lead time for these equipments. Manufacturers have expressed confidence that they can meet peak demand in 1984. (Reference No. 44) However, failure to order well in advance of need could cause delays and escalate costs.

4. Pressure Vessels and Reactors: Although synfuels demand will exceed 25% of productive capacity, suppliers are confident that they can meet demand (Reference No. 45). There is slack in the system due to slow economic growth and the absence of demand for nuclear reactor vessels (Reference No. 43).

5. Alloy and Stainless Steel Valves: Demand for specialized valves will exceed 25% of current productive capacity (Reference No. 45). Manufacturers' ability to expand productive capacity hinges on:

   - adequate lead planning time
   - availability of chromium, molybdenum and cobalt
   - availability of quality castings and forgings
   - availability of qualified machinists (Reference No. 44)

6. Draglines: Draglines, which are essential for coal surface mining operations, have a lead time of 2-2-1/2 years. However, no production constraints are likely if firm orders are placed in advance of need.

7. Air Separation (Oxygen) Equipment: Reference No. 46 identified air separation plant fabrication capacity as the "most severe single constraint." The critical components identified were aluminum distillation towers which are currently shop fabricated and brazed aluminum heat exchangers used in these towers. Techniques for field fabrication (to maintain quality control) have not been perfected. Development of acceptable field fabrication could reduce this potential constraint. Added reliance on production in Western Europe and Japan could also help, assuming that transportation facilities were available.

8. Distillation Towers: A specially constructed facility.

The accompanying Exhibits 5.1 and 5.2 (Reference Nos. 44) summarize the equipment supply constraints for a 1 MMBD and a 3 MMBD scenario (2000);

Performance Constraints--the possible failure to perform to specifications at operating conditions.

Concerns with ability to meet specific performance standards have been expressed for five categories of equipment as follows:

1. Gasifiers
2. Extractors
3. Hydrotreaters
4. Oxygen compressors
5. Coal slurry heaters

The available operational data for these five categories of equipment are from useages in process environments which are significantly different from the coal conversions regimes in liquid synfuels facilities. Substantial development will be required to modify and/or scale up equipment currently in commercial use (Reference No. 47). Therefore, these five categories of equipment impose potential constraints to the synfuels industry which would result from equipment failure or substandard performance.

5.2.2 Critical Materials

Materials critical to the synfuels program are cobalt, nickel, molybdenum and chromium. After two independent analyses, only chromium was identified as a potential constraint (Reference NO.44,46) . U.S. currently imports over 90 percent of its chromium use and will remain highly dependent on foreign supply. Demand for chromium by synfuels programs could reach 7% of total U.S. demand. Exhibits 5.1 and 5.2 depict this concern.

5.2.3 Manpower

Technical Laborforce

Engineering design manhour requirements for construction of synfuels facilities are 1.5 to 3 times greater than those

EXHIBIT 5.1 (Reference 44)

POTENTIALLY CRITICAL MATERIALS AND EQUIPMENT REQUIREMENTS FOR COAL LIQUIDS PLANTS AND ASSOCIATED MINES

(3MMBPD Scenario)

Category	Units	Peak Annual Requirements	Us. Production Capacity	Requirements Percent of Production
Chromium	tons	10,400	400,000[1]	3
Valves, alloy and stainless steel	tons	5,900	70,000	8
Draglines	yd	2,200	2,500	88
Pumps and drivers (less than 1000 hp)	hp	830,000	20,000,000	4
Centrifugal Compressors (less than 10,000 hp)	hp	1,990,000	11,000,000	18
Heat Exchangers	ft^2	36,800,000	50,000,000[2]	74
Pressure Vessels (1.5-4” Walls)	tons	82,529	671,000	12
Pressure Vessels (greater than 4" wall)	tons	30,785	240,000	13

[1] Current consumption

[2] Total for surface condensers, shell and tube, and fin-type.

EXH B T 5.2 (Reference 44

Table 1-8

SELECTED MATERIAL AND EQUIPMENT ITEMS REQUIRED TO MEET PROJECTED COAL LIQUIDS PLANTS (AND ASSOCIATED MINE) NEEDS

Category		* Peak Annual Requirement and Year				Production Capacities			
		1 MMBPD Scenario		3 MMBPD Scenario		US	Japan	Europe	Total
Stainless Steel	(tons)	81,733	(1986)	52,299	(1985)	1,954,000	1,988,000	N/A	3,942,000+
Aluminum	(tons)	2,705	(1985)	6,443	(1985)	4,800,000	N/A	N/A	8,735,000
Chromium	(tons)	4,364	(1985)	10,409	(1985)	400,000(1,2)	N/A	N/A	N/A
Nickel	(tons)	756	(1986)	1,805	(1985)	114,000	72,000(3)	35,000	221,000
Cast Iron	(tons)	23,195	(1986)	55,610	(1985)	16,200,000	979,000	10,648,000	27,827,000
Iron and Steel Forgings	(tons)	5,766	(1985)	14,323	(1986)	1,416,000(1)	867,000	2,681,000	4,964,000
Steel Plate > 1.5"	(tons)	26,647	(1986)	63,767	(1985)	1,900,000	14,000,000	1,540,000	17,440,000
Pipe, Alloy and Stainless Steel	(tons)	9,818	(1999)	24,545	(1999)	1,852,000(1)	3,000,000	2,176,000	7,028,000
Valves, Alloy & Stainless Steel	(tons)	2,481	(1985)	5,892	(1984)	70,000	68,000	97,000	235,000
Reinforcing Bar	(tons)	23,503	(1985)	64,886	(1985)	6,187,000(1)	14,436,000	10,161,000	30,784,000
Draglines	(yd³)	810	(1987)	2,196	(1987)	2,500	N/A	N/A	N/A
Pumps & Drivers < 1,000 hp	(1,000 hp)	343	(1985)	830	(1984)	20,000	N/A	N/A	N/A
Centrifugal Compressors & Drivers > 10,000 hp	(1,000 hp)	194	(1985)	481	(1984)	15,000	N/A	N/A	N/A
Centrifugal Compressors & Drivers < 10,000 hp	(1,000 hp)	833	(1985)	1,989	(1984)	11,000	N/A	N/A	N/A
Heat Exchangers	(1,000 ft²)	15,260	(1986)	36,780	(1985)	50,000	82,000	N/A	132,000+
Non-Nuc Pressure Vessels 1.5-4" wall	(tons)	33,677	(1985)	82,529	(1984)	671,000	223,000	132,000	1,026,000
Non-Nuc Pressure Vessels > 4" wall	(tons)	12,314	(1995)	30,785	(1999)	240,000	254,000	99,000	604,000
Boilers	(MM lb/hr)	8	(1985)	19	(1985)	210	N/A	N/A	N/A

N/A = Not available
1) Current consumption
2) US dependent upon foreign supplies
3) Includes other Asian countries

*Peak refers to maximum annual requirements

SOURCE: E. J. Bentz & Associates

needed for refinery construction. Indirect synfuel processes are the most engineering intensive since they are, in effect, two separate systems, 'e.g., gasification and synthesis. However, even the direct liquefaction process requires significant amounts of engineering design manpower (Reference No. 45). The need for chemical engineers would be the area of greatest concern. Under a scenario projecting 3 million B/D by the year **2000,** demand for chemical engineers increases significantly between now and 1985 (Reference No. 440. An additional 1300 chemical engineers representing a 35% increase in this specialty, i.e. , a 35% increase in the process engineering work force, as found in previous design and project work at present (in 1979: 3600 chemical engineers) in less than six years would be required for the synfuels program= Engineering schools can generate new inexperienced chemical engineers to meet this demand and qualified chemical engineers will remain a scarce and expensive commodity. Demand for other engineering skills will also increase but at a more manageable rate. It should also be realized that potential growth in other sectors--such as defense needs for engineering and construction skills--may also place an added demand On skill availability.

Construction Laborforce

Skilled craftsmen such as welders, boilermakers, pipefitters and electricians are already in short supply. These shortages have been exacerbated over the last decade by increasing reluctance on the part of craftsmen to follow construction work and relocate. Since many of the synfuels development projects would be located in areas with existing overall manpower shortages and virtually no existing pool of skilled manpower, labor could become a significant constraint. Using the 3 million B/D scenario, this industry would require 73,000 construction employees in 1986, the peak year. This is approximately **2%** of the entire construction employment force (Reference No. 44). More training programs and use of "nonjourneymen" or "helpers" to supplement the workforce could reduce potential shortages. Recruitment of women and minorities would help also. However, some of these steps might be opposed by labor unions. Labor unions are particularly concerned that open-shop (non-union) construction companies will gain a foothold in this program. The accompanying Exhibits 5.3, 5.4 and 5.5 (Reference No. 44) , summarize the construction manpower requirements under the 1 MMBD and 3 MMBD scenarios.

5.2.4 Coal Supply

Chapter **2** has discussed U.S. coal supplies. In brief, the U.S. coal industry currently has approximately 100 million tons of productive capacity which is not being used. In addition, the coal industry traditionally has

EXHIBIT 5.3 (Reference 44)

TOTAL ENGINEERING MANPOWER REQUIREMENTS FOR COAL LIQUIDS PLANTS AND ASSOCIATED MINES

3 MMBPD SCENARIO
(Persons)

Scenario	1984	1990	2000
All Engineering Disciplines			
Design and Construction	8,500	5,200	6,300
Operation and Maintenance	____	2,200	4,800
Total	8,500	7,400	11,100
Chemical Engineering			
Design and Construction	1,300	740	920
Operation and Maintenance	____	1,050	2,250
Total	1,300	1,790	3,170

EXHIBIT 5.4 (Reference No. 44)

PROJECTED PEAK CONSTRUCTION LABOR REQUIREMENTS
(Persons)

Craft	1 MMBPD Scenario (1987)	3 MMBPD Scenario (1986)
Pipefitters	7,170	**16,920**
Pipefitters-Welders	2,400	**5,600**
Electricians	3,020	**7,190**
Boilermakers	660	**1,570**
Boilermaker-welders	130	**310**
Iron Workers	1,760	**4,250**
Carpenters	2,700	**6,400**
Other	12,830	**30,660**
Total	30,670	72,900

EXHIBIT 5.5 (Reference No. 44)

REGIONAL MANUAL LABOR FOR CONSTRUCTION AND MAINTENANCE FOR COAL LIQUIDS PUNTS AND ASSOCIATED MINES

Craft	Current Union Craftsmen[1]	Coal Liquids Program Peak Requirements[2]	
		3 MMBPD Scenario	1 MMBPD Scenario
Pipefitters (including welders)			
East North Central and East South Central Regions	37,672	10,300	6,300
West North Central and Northern Mountain Regions	14,498	11,800	6,900
Boilermakers (including welders)			
East North Central and East South Central Regions	5,260	900	500
West North Central and Northern Mountain Regions	2,075	1,100	600
Electricians			
East North Central and East South Central Regions	36,860	3,300	2,000
West North Central and Northern Mountain Regions	12,662	3,700	2,200

[1] Source: Construction Labor Research Council

[2] Source: Obtained by computer run of Bechtel Corporation Energy Supply Planning Model, as described in reference 44.