CHAPTER 5: SUPPLY DEPLOYMENT SCENARIOS FOR SYNTHETIC FUELS

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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 he 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 existinq 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.j

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 Ex-changers	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.

EXHIBIT 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	(1986)	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)	18,200,000	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)	54,886	(1986)	6,187,000(1)	14,436,000	10,161,000	30,784,000
Draglines	(yd^3)	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 ft^2)	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	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.

surge capacity which is brought on line whenever the spot price of coal increases sharply. The lead time for opening up new mine capacity, both surface and deep, ranges between three and five years. Since the construction of major synfuels plants takes the same length of time, adequate new coal supply can be brought on line in a timely fashion. Finally, the U.S. coal resource is so large that it is very unlikely that there would be supply shortages over the next century. For all these reasons, coal supply poses no constraint to synfuels development.

5.2.5 Water Supply

Chapter 2 has discussed water supply concerns. Also reference 31 discussed these in detail. In brief, while the U.S. has abundant water supplies in aggregate, there are certain specific geographic locations where water supply could become a constraint to development of a large synfuels program. This is particularly true in the semi-arid portions of the West where significant coal reserves are located.

> ". . . sufficient water physically exists to support a significant-sized synfuel industry in the Upper Missouri and Upper Colorado River Basins, the primary western fuel resource areas." (Reference No. 33)

The problems with water supply in these areas are institutional and highly political and often emotion-laded. Thus far energy developers have been able to purchase water rights from farmers or Federal and State water impoundments. As long as a relatively full market exists for the transfer of water rights, energy developers can afford to bid away the required water supply. In addition, corporate planners will need to consider water supplies for the construction/operating laborforce, their families, and the communities which-will support them.

5.2.6 Environmental Health and Safety

Standards and Requirements

The liquid synfuels technologies "appear to have no absolute environmental protection constraint that would universally limit or prohibit deployment." (Reference No. 33) However, the direct liquefaction processes have some potential to expose workers or the public to toxic and carcinogenic materials. Such risks could be judged politically and socially unacceptable and could become a development constraint. The Prevention of Significant Deterioration program under the Clean Air Act could pose absolute limits to the number of plants able to locate in a specific geographic area since the allowable increments of ambient air quality could be fully utilized. In the case of oil shale where the resource base is concentrated in a specific area in and adjacent to Northwest Colorado, PSD limits are very likely to constrain the number of facilities permitted. These limits, still to be developed, have not yet been set. Ranges of capacity vary, however, on what is possible. In addition,

> "Some yet-to-be-defined regulations, if promulgated in their stringent forms, appear capable of severely limiting a number of synfuel technologies. These regulations include air quality emission control measures for visibility, changes in the original prevention of significant deterioration (PSD) regulations, extension of PSD limiting increments to other pollutants, short-term nitrogen oxide ambient standards, development of hazardous waste tests and regulations and special waste regulations, toxic product regulations, and occupational safety standards." (Reference No. 33)

A detailed assessment of the environmental, health, and socio-economic impacts is found in reference no. 31 .

Permits and Licenses

The permitting and licensing process is complicated and time consuming. However, it poses no direct constraint on the synthetic fuels deployment program. The process generates procedural delays and provides multiple access to various public interest groups opposed to specific projects, specific technologies, or specific sites. More importantly, the process can be used by local political jurisdictions to either force project relocation or extract concessions from the project developers. Permit considerations are specifically discussed in the project discussions to follow.

5.2.7 Siting

Siting constraints are discussed in detail by the author in reference 31 . In brief, Physical availability of sites is not a constraint. However, optimal siting by industry using their objective function often conflicts with the goals of other interest groups. Since much of the synfuels development will occur in areas with low population density, "conflicts will arise between the rural social order which currently exists in the region and the new urbanized society which will accompany growth. Early planning is required to handle these impacts." (Reference No. 45)

To overcome the "locate your plant anywhere but not here" syndrome, corporate planners will have to work closely with state and local officials as well as with numerous civic associations. This requires full consideration of the secondary effects of development on the infrastructure of the immediate and surrounding areas. These by their very nature are site specific analyses. What new roads, schools, services, homes and institutions will be required? How will these requirements be funded? Can the community be protected against the worst features of the "boom" scenario and from the downside risk of bust? What does happen if the project fails and is abandoned? These are reasonable questions which often do not have reasonable answers. References 31 and 32 have discussed these key problems.

5.2.8 Transportation

Transportation constraints can be a key concern. They must be considered on a regional/site specific basis. Reference 18 has treated these concerns.

As discussed earlier in Chapter 4, transport costs can be a key part of delivered cost. As discussed later in this chapter, the availability of inexpensive bulk transportation is crucial to project development.

5.2.9 Tradeoffs

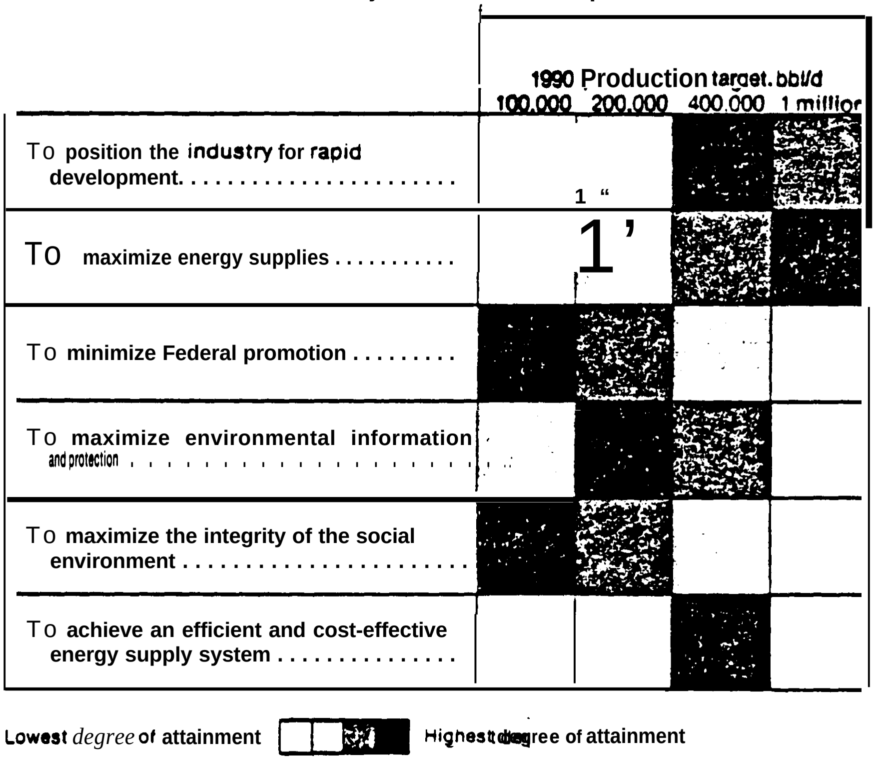
Hence, energy supply deployment will be affected by many competing constraining factors. Any specific project consideration must provide for a best optimum solution. This is clearly seen in Exhibit 5.6 in the variation to which oil shale targets would be achieved subject to different goals (Reference No. 8).

We will now look at our development of alternate supply scenarios.

EXHIBIT 5-6

ALTERNATE SHALE OIL PRODUCTION TARGETS (reference 8)*

-The Relative Degree to Which the Production Targets Would Attain the Objectives for Development



SOURCE Office of Technology Assessment.

*Shale oil product ion targets are affected by many technical, environment al, and socioeconomic factors. As described in reference 8, the OTA has assessed the variation of 1990 production targets with regard to many of these key factors.

e jb &a

5.3 Development of Supply Deployment Scenarios and Comparisons With Other Estimates

(A) Shale Oil

The oil shale industry*is in an advanced stage of development compared to other synfuel processes such as direct coal liquids. Design and construction (not including permiting) for an oil shale facility is typically in the 3-5 year time frame. Permiting requirements vary with two years being a typical time period. Most proposed/being developed projects are located in the West in the Green River Formation in Colorado, Utah, and Wyoming (Piceance, Uinta, Green River, Fossil, Great Divide, Washakie, and Sand Wash Basins) . Eastern shale development using promising new technical advances, discussed in Chapter 3, are likely to come on later. As discussed in the opening section, constraints center about resolution of land lease issues (the federal government owns over 80% of oil shale lands) , environmental and water availability issues, and availability of skilled labor, especially hard rock miners.

Table 5-1 lists the potential commercial scale projects, identifying their proposed location, process, estimated start up, and project scale (production). In addition, the Department of Energy is conducting above--ground and advanced retorting projects.** At present, permiting has been obtained for: Colony (final EIS, and a conditional PSD for 50,000, BPD complex), Union (final EIS for a 10,000 BPD commercial demonstration module unit) , Occidental (conditional PSD), Superior (final EIS) , and Paraho (draft EIS) . Based on the above projects planned, as well as individual surveys, scenario build-up rates are shown in Table 5-2. Comparisons of these rates with other estimates are shown in Table 5-3. This information is current as of 12/80.[p]

Initial production of shale, expected in the West, is expected to be treated (upgraded/refined) in the Rocky Mountain region, and will utilize existing spare refinery capacity. The next anticipated sequential market area is the Midwestern refinery region utilizing current in-place pipeline capacity (to the extent that anticipated new crude finds in the Overthrust Belt will not absorb pipeline capacity) . The key markets envisioned for shale oil is as refinery feedstocks producing a large middle distillate slate for anticipated growing middle distillate needs (such as diesel oil). Shale oil residuals have also been proposed for use in turbines (current tests being sponsored by EPRI at Long Island Lighting) . Using a typical refinery product slate, estimated shale-derived products are depicted in Table 5-4.

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*I.e., the industrial interests (oil, chemical, as identified in table 5-1) that are comprising the newly created shale industry.

**Private communication, DOE 12/80.

TABLE 5-1: POTENTIAL COMMERCIAL SCALE PROJECTS - SHALE OIL

PROJECT	SITE	PROCESS	PROJECT SIZE (1 OOOB/D)	EST START UP	APPROX. COST (B$)
COLONY DEVELOPMENT (Exxon, Tosco) STATUS : $75 million spent to-date; planning, detailed engineering design and cost- ing completed; construction suspended; Exxon recently bought 60% share with con- tingencies tied to 1985 start-up; Tosco may seek Federal loan guarantee to raise its share of capital	co	Surf ace Retort	47	1985	1.7 (1980$)
UNION OIL STATUS: All permits received to construct and operate 9000B\D experimental retort which will be done with pri- vate financing (and $3 tax credit) ; 50,000B/D project depends on results of experi- mental retort.	co	Surface Retort	50	1983 (9000B/D)	
TOSCO SAND WASH STATUS: $2 million spent by end of 1978; planning ex- ploration, and environmental analysis; TOSCO could use technology developed for Colony project, but would have to raise capital for both projects.	UT	Surface Retort	47	1988	
RIO BLANCO (GULF, STANDARD OF INDIANA) STATUS: $245 million spent to-date; shaft sinking & surface construction activit- ies; further action pending Federal incentive programs.	co	Mod In Situ & Surface	76	1988	

TABLE 5-1 (Continued)

PROJECT	SITE	PROCESS	PROJECT SIZE (1000B/D)	EST START UP	APPROX. COST (B$)
OCCIDENTAL-TENNECO STATUS: Site preparation & shaft sinking; detailed development plan.	co	OXY Modified In-Situ	50	1986	
WHITE RIVER SHALE PROJECT (Phillips, Sun, Sohio) STATUS: Detailed development plan completed. Environmental monitoring continuing. $86 million spent to-date. Title status cleared by Supreme Court decision.	UT	Surface Retort	50 to 100		
SUPERIOR OIL STATUS: Pilot studies completed; environmental analysis . underway at BLM; feasibility studies underway; pending land exchange appears to be contrary to current DOI policy.	co	Surface Retort	13 + minerals		
PARAHO DEVELOPMENT STATUS: Beginning feasibility study (DOE funded) .	UT	Surface Retort	30	1984	
GEOKINETICS STATUS: Beginning DOE funded feasibility study.	UT	Surface Retort	2 to 8	1985	
TRANSCO ENERGY STATUS: Beginning DOE funded feasibility study.	KY	IGT Hytort	50	1984	
CHEVRON STATUS: Recently announced initiation of feasibility study.	co	Surface Retort	50		

SOURCE: E. J. Bentz & Associates

TABLE 5-2: SHALE OIL BUILD-UP SCENARIOS*
(in units of 50,000 MMBP)
OF CRUDE OIL EQUIVALENT

Scenario	1980	1985	1990	1995	2000
A Capacity added in period		.5	7.5	.5	0
Total Capacity		.5	8	9	9
B Capacity added in period		.5	9.5	8.5	.5
Total Capacity		.5	10	18.5	19

NOTE: Most shale plants are estimated to be sited in the Green River Formation (Colorado, Utah, Wyoming).

* Shale oil build-up scenarios were constructed using interviews and referenced literature as cited in table 5-1, text, and footnote p.

SOURCE: E. J. Bentz & Associates

TABLE 5-3: OIL SHALE DEPLOYMENT SCENARIOS : 1980-2000
(thousands of barrels per day of crude oil equivalent)

Source	1980	1985	1987	1990	1992	1995	2000
U.S. DOE[1] (2/80)	--	80	225	400	450	450	450
Scenario A	--	25		400		450	450
DR1[2] (10/79)	--	185	350	700	800	925	950
National Energy Plan II (5/79)							900-1300
U.S. DOE[5] (11/80)	--	25	160	400-500	550-800		
Scenario B	--	25		500		925	950
OTA[4] (6/80)			400				
Shell[5]			150				

*NOTE: Most proposed shale projects are in the West, in the Green River Formation in Colorado, Utah, and Wyoming.

Interpreted from:

[1] U.S. DOE "Oil Shale Industrialization Action Plan," Feb. 1980.

[2] Denver Research Institute, 10/79.

[3] U.S. DOE Synfuel Corporation Planning Task Force, private communication, 11/80 and 12/80.

[4] OTA--An Assessment of Oil Shale Technologies, 6/80.

[5] U.S. National Energy Outlook 1980-1990, Shell Oil Co., 2/80. Shell--U.S. National Energy Outlook, Feb. 1980.

SOURCE: E. J. Bentz & Associates

TABLE 5-4: ESTIMATED TYPICAL SHALE OIL PRODUCT SLATE: * 1980-2000
(thousands of barrels per day of crude oil equivalent)

Scenario	Products	1980	1985	1990	1995	2000
A	Gasoline		4.25	68	77	77
	Jet Fuel		5.0	80	90	90
	Diesel Fuel	-	13.5	216	243	243
	Residues		2.25	36	41	41
B	Gasoline		4.25	85	157	162
	Jet Fuel		5.0	100	185	190
	Diesel Fuel	-	13.5	270	500	513
	Residues		2.25	45	83	86

* Table values derived using Table 5.2 values, and typical yield slates (Chevron Research, 1978 reference: "Refining and Upgrading of Synfuel From Coal and Oil Shale by Advanced Catalytic Processes") discussed in Chapter 4, Section 6.

Because of relatively higher hydrogen content and lower aromatic concentration (than in general to coal liquids) , a "natural" product slate from shale oil is a mixture of gasoline, diesel, and jet fuel.

SOURCE: E. J. Bentz & Associates

(B) Coal Gases

As shown in the accompanying project tables, there is a significant level of varied activity in the coal gases area. Key generic processes are low/medium Btu gas and pipeline quality H-Btu gas.

Low/Medium Btu Gas

As discussed in Chapter 3 and in the Appendix, leading technologies include the regular and slagging Lurgi gasifier (especially in earlier years) , Texaco, Westinghouse, Koppers, and Winkler gasifiers.

Since low/medium Btu gas offers industrial and utility users a relatively curtailment-free source of high quality fuel and chemical feedstock, it is expected that they will penetrate into the utility and chemical market. The Energy Security Act specifically exempts medium Btu gas from allocation and pricing regulations.

Low-Btu gas finds key market use as industrial fuels in such applications as kilns, small boilers, and chemical furnaces. At present it has been estimated that there are about 15-20 domestic facilities (Reference No. 48) that are beginning to use low Btu gas for these applications. These include chemical firms such as Dow Chemical as well as automotive giants such as General Motors.

The Glen Gery Corp. has itself four facilities gasifying coal to produce a fuel gas to fuel their brick kilns, while Caterpillar Tractor plant in York, Pennsylvania produces fuel gas for heat treating furnaces. NCA (8/80) estimates there are nine commercial plants (in operation, under construction, or in proposal/planning stage). It has been estimated (Reference No. 50) that low Btu gasifiers are feasible at approximately 3500 industrial plant sites. These plants are expected to be geographically located at coal/adjacent to available coal suppliers.

Medium Btu gas serves several markets. Among them are utilities and chemical feedstock markets. Medium-Btu gas could be used as a synthesis gas for producing chemical products (ammonia, fertilizers, plastics) , as well as utility power. Similarly, steel industry uses fuel for blast furnaces and annealing operations.

A potential co-product, methanol, could also be used as a utility peak showing fuel in turbines, or as an automotive fuel (Reference No. 51). Medium-Btu gas can also be used in utility use in a combined cycle power generation mode. NCA (Reference No. 48) estimates there are five commercial scale plants in the proposed/planning stage. Key demonstration plants at TVA, Memphis Industrial Fuel Use Plant, and Cool Water, California (Southern California Edison), are in advanced stages. It has been estimated (Reference No. 50) that there are approximately 350 potential sites for single user or limited distribution medium Btu gasifiers. In addition, there are combined-cycle markets (Reference No. 51). As shown on the accompanying tables (and NCA survey), likely locations for medium Btu facilities include Louisiana, Texas, Arkansas, Pennsylvania, New Mexico, California, Tennessee, Montana, Virginia, and Illinois. Table 5.5 lists the key proposed projects under way.

Table 5-7 gives the scenario deployments of medium Btu/L Btu gas. The rate build-up was estimated by review of the cited data tables, on-line surveys, and judgmental interpretation with alternate comparative estimates.

H-Btu Gas

As shown in the accompany table (Table 5-6), of proposed commercial scale projects most early H-Btu gas development will occur in the West, especially in the states of North Dakota, Wyoming, Utah, New Mexico, and Montana (Northern Great 'Plains Regions and Rocky Mountain Region). Construction is at present underway in North Dakota on the Great Plains Gasification project. As shown in the table, this plant could be producing by 1984, with a production of 138 mmscf/day, at which time a second plant would begin (an additional 138 mmscf/day). Later plants are expected to be deployed in the Southwest (Texas, Louisiana, Arkansas, Oklahoma), and in the East (Pennsylvania), and capture the use of existing transportation lines.

The predominant end use for H-Btu gas is space heating (industrial/commercial). Industrial use of the gas will be in the chemical, utility, and steel, iron and glass products industries (i.e., large current users of natural gas). Market penetration will be affected by the pricing treatment of gas (e.g., rolled-in pricing) over the estimation period (period of natural gas deregulation). Table 5-7 gives the scenario deployments of H-Btu gas over the estimation period. It is based on judgmental interpretation of the plant-specific build-up data cited, and on-line survey results. Table 5-8 gives the comparison of the scenario estimates with those of other sources.

TABLE 5-5 : POTENTIAL COMMERCIAL SCALE PROJECTS - LOW/MED BTU GAS

I. THE FOLLOWING PROJECTS ARE CURRENTLY UNDER DEVELOPMENT

(12/80)

PROJECT	SITE	PROCESS	PROJECT SIZE (1000BOE[D)	APPROX . COST (B$)
REYNOLDS ALUMINUM CO. APPLICATION: Power Generation for Aluminum Reduction	VA			
can-/do* APPLICATION: Industrial Gas	PA			
MUNICIPAL UTILITIES BOARD APPLICATION: Industrial Gas	AL			
PANHANDLE EASTERN APPLICATION: Industrial Gas	TX		8	
MEMPHAS GAS* APPLICATION: Utility\Feedstock (construction begins in 1982)	TN			0.3
SAN DIEGO P & L APPLICATION: Utility/Feedstock	CA			
ILLINOIS POWER COMPANY APPLICATION: Utility--Combined Cycle (1982 target)	IL		2	0.1
SOUTHERN CALIFORNIA EDISON APPLICATION: Utility--Combined cycle	CA		3	0.3
HOUSTON NATURAL GAS APPLICATION: Utility/Feedstock	LA			
COOLWATER APPLICATION: Utility-Combined Cycle (1984 target)	CA		100MW	0.2

*These projectsarecurrently funded as part of the Fossil Energy Technology Demonstration Program. (12/80)

TABLE 5-5: (I Continued)

PROJECT	SITE	PROCESS	PROJECT SIZE (10 00BOE/D)	APPROX. COST (B$)
MID-WEST ENERGY COAL ALTERNATIVE, INC. APPLICATION : Industrial Fuel/ Feedstock	IL			
CARTER OIL APPLICATION : Industrial Gas and Feedstock	TX			
ENERGY CONCEPTS APPLICATION: Electric Generation and/or Feedstock	OH			

SOURCE: E. J. Bentz & Associates

TABLE 5-5 (Continued)

II. THE FOLLOWING PROJECTS RECENTLY RECEIVED DOE FEASIBILITY GRANTS (PL-96-126)

PROJECT	SITE	PROCESS	PROJECT SIZE (1000B/D)	EST START UP
UNION CARBIDE APPLICATION: MBG+H_2 for fuel and feedstock	TX	Texaco	21.550	1988
GENERAL REFRACTORIES APPLICATION: LBG fuel to kiln for Pearlite Mfg.	KY	Wellman-Galusha	1.034	1983
CENTRAL MAINE APPLICATION: Combined cycle power- (new)	ME	Texaco	14.100	1987
FLORIDA POWER APPLICATION: Combined cycle repower	FL	BGC-Lurgi	7.458	1985
TRANSCO APPLICATION: MBG to existing power plants	TX	Lurgi	21.550	1985
PHILADELPHIA GASWORKS APPLICATION: MBG-fuel gas	PA	TBD	3.448	1985
EG&G APPLICATION: Combined cycle power & methanol	MA	Texaco	28.500	1986

NOTE: Over 40 proposals were received in response to 3/79 Notice of Program Interest. About 50 proposals were received in response to Feasibility and Cooperative Agreement Solicitations under P.L. 96-126. PL 96-304 programs are not listed due-to the funding uncertainty associated with the current recission order.

TABLE 5-6: POTENTIAL COMMERCIAL SCALE PROJECTS--HIGH BTU GAS

PROJECT	SITE	PROCESS	PROJECT SIZE (1000BOE\D)	EST START UP	APPROX. COST (B$)
GREAT PLAINS GASIFICATION STATUS: $40 million spent for project design and environmental work. All permits obtained but final FERC tariff to market the gas. DOE cooperative agreement & loan guarantee under P.L. 96-126. Plant could be producing by 1984. A second plant with additional 138 mmscf/day is contingent on the results of Phase 1.	ND	Lurgi	25 (138mmscf/d)	1984 earliest	1.5
WYCOAL GAS INC. STATUS: Recently received DOE cooperative agreement to develop definitive design, estimate costs, secure permits and approvals, obtain financing and identify long-lead delivery items; market is company owned pipeline to mid-West. Second phase would add a second 150 mmscf/d.	wy	Lurgi & Texaco	25 (150mmcf/d)		
EL PASO NATIONAL GAS STATUS: Initial 1972 application to FPC placed in abeyance. Coal commitment obtained; water lease expected; FERC tariff required before construction.	NM	Lurgi	13 (72mmscf\d)	earliest 1986	.6
TEXAS EASTERN/TEXACO STATUS: Water and coal from Texaco's Lake Desmet Reservoir property. Recently announced privately financed feasibility study.	WY	Lurgi	50 (275mmscf/d)	could be operative by 1990	

TABLE 5-6 (continued)

PROJECT	SITE	PROCESS	PROJECT SIZE (1000 BOE/D)	EST START UP	APPROX. COST (B$)
PANHANDLE EASTERN PIPELINE COMPANY STATUS: Coal and water commitments have been obtained. No filing yet before FERC. Second 135 mmscf/day stage if justified by first stage results.	WY	Lurgi	25		2.
MOUNTAIN FUEL COMPANY STATUS: Feasibility study under way. No filing before FERC to date.	UT	Lurgi	50 (275mmscf/d)	1990	
NATURAL GAS PIPELINE CO. OF AMERICA STATUS: Preliminary engineering design completed. No filing before FERC.	ND	Lurgi	50 (275mmscf/d)	late 1980s	
TEXAS EASTERN SYNFUELS STATUS: Beginning DOE funded feasibility study.	NM	Lurgi	43 (sng+MEOH)	late 1980s	
CROWE TRIBE OF INDIANS STATUS: Beginning DOE funded feasibility study.	MT	Lurgi	22	1987	

*Refers only to PL 96-126 feasibility and cooperative agreements. PL 96-304 project programs are not listed due to funding uncertainty associated with the current budget recission order.

SOURCE: E. J. Bentz & Associates

TABLE 5-7: SCENARIO DEPLOYMENT: H-Btu GAS AND MED/LOW Btu GAS

(EXPRESSED IN MMBD AND 50,000 BPD PLANT UNITS)

SCENARIO			1985	1990	1995	2000
H-Btu Gas (A)	Added Capacity in period (MMBD)	(# plants) (50,000 BPD)	.025 (.5)	.155 3.1	.20 (4)	.12 2.4
	Total Capacity	(# plants)	.025 .5)	.180 (3.6)	.380 (7.6)	.50 (10)
H-Btu Gas (B)	Added Capacity in period MMBD)	(# plants) (50,000 BPD)	.025 .5	.[illegible]5 (7.5)	.350 [illegible]7)	.250 (5)
	Total Capacity	(# plants)	.025 (.5)	.400 (8)	.750 (15)	1.0 (20
Med/Low Btu Gas (A)	Added Capacity in period (MMBD)	(E plants) (50,000 BPD)	.06 (1.2)	.115 (2.3)	.125 (2.5)	.10 (2)
	Total Capacity	(# plants	.06 (1.2)	.175 (3.5)	.30 (6	.40 (8)
Med/Low Btu Gas (B)	Added Capacity in period (MMBD)	(# plants) (50,000 BPD)	.06 (1.2)	.19 (3.8)	.15 (3)	.10 (2)
	Total Capacity	(# plants	.06 (1.2)	.25 (5)	.40 (8	.50 10)
Sum (A)	Total Capacity (MMBD)		.085 (1.7)	.355 (7.1)	.680 (13.6)	.90 (18)
SUM (B)	Total Capacity (MMBD)		.085 (1.7)	.65 (13)	1.15 (23)	1.50 (30)

SOURCE: E. J. Bentz & Associates; scenarios constructed using interviews and referenced literature cited in text, footnote q, at tables 5.5 and 5.6.

TABLE 5-8 : SYNTHETIC COAL GASES COMPARISONS

Source	1980	1985	1990	1992	1995	2000
National Energy Plan[1] (May 1979)						.8-1.0
Frost & Sullivan[2]			.8			2.2
Exxon[3]			.5			.7-1.5
U.S. DOE[4]		.05	.36	.63		
Shell[5]		.19	.49			
Scenario A		.085	.355		.680	.9
Scenario B		.085	.65		1.15	1.5

[1]U.S. National Energy Plan II.

[2]As reported in Synfuels, 2/80.

[3]Exxon Energy Outlook, 12/79.

[4]Private communication, DOE.

[5]Shell National Energy Outlook, 2/80.

SOURCE: E. J. Bentz & Associates

(c) Coal Liquids

As discussed in earlier chapters, coal liquids consist of indirect liquefaction of coal (Fischer-Tropsch liquids, methanol, methanol-gasoline) , and direct liquid processes (H-coal, EDS, SRCII) . As shown in the accompanying Table 5-9, all early (to 1990) commercial scale projects receiving current government support are in the indirect category, although several direct liquefaction proposals have been received. As such, indirect liquefaction liquids are expected to dominate coal liquids product in the later decades of the century. At present, the only commercially demonstrated coal liquefaction process is the Fischer-Tropsch process used in the SASOL plants in South Africa (described in Chapter 3) . This process technology, an indirect liquefaction technology, is being adopted and improved for use in the U.S. The other key indirect liquefaction processes are methanol production-- a well known commercial process technology, and Mobil-M methanol-to-gasoline process, which should be commercially demonstrated within several years. In addition to several U.S. funded domestic studies for M-gasoline (see Table 5-9), there is a pilot plant demonstration project in Germany (Reference-No. 48) , and a natural gas-methanol-M-gasoline commercial project scheduled for operation -in New Zealand by mid-80's (Reference No. 49). At present, there are no "commercially available direct liquefaction processes. The government has jointly (with industry) funded an SRC 1l demonstration plant and an
EDS, and H-coal pilot plants for operation in mid-80's. Including the government sponsored study projects, there have been a total of 13 commercial plants, 4 demonstration plants, and 4 pilot plants are proposed/or in operation in the U.S. (Reference No. 18).

The anticipated deployment, based on judgmental interpretation of individual planned projects, current survey work, and individual project reviews, is depicted in the accompanying Table 5-9. As expected, indirect liquefaction processes dominate throughout, with direct liquefaction processes coming on stream late in the century. Early deployment is expected in the Northern Great Plains and Southwest region to capture existing product pipeline capacity (and water transport) and to fill energy product demands. Direct liquefaction developments are projected to come on in the 90's, and focus their activities in the Appalachian and Interior coal regions.

Direct liquid conversions naturally produce a high fraction of heavy oils. Since the traditional market for heavy oils (utility and industrial boilers) will probably convert to direct combustion of coal and medium Btu gas, upgrading of product slates into other market fuels is probable. Gulf's "Phase Zero Study" to DOE (also see Market Applications for SRC-11 products, Proceedings of the Sixth Annual International Conference on Coal Gasification, Liquefaction and Conversion of Electricity, Univ. of Pittsburgh, July 31-August 2, 1979) identified a substantial market where coal-derived liquid boiler fuels would have a distinct economic advantage over coal combustion with flue gas desulfurization primarily in congested areas of the Northeast where retrofitting to include flue gas desulfurization is expensive. As an example, projected EDS product slate usage could consist of stationary turbine fuels, special marine diesel fuels, and potentially home heating oils.

In general, direct coal liquefaction yields a high fraction of heavy fuel oil products. Current R&D work (at the laboratory stage) aims at upgrading this yield to the middle distillate, and naptha portion, thus minimizing the residual portion. However, this requires considerable upgrading by hydrogeneration or hydrotreating, as discussed in Chapter 4. In general, the products will be much more aromatic than equivalent petroleun-based products (private communication, Exxon Company, USA, 10/80) .

Indirect liquids such as Mobil-M gasoline and methanol have projected use in transportation, and transportation/utility peak usage respectively. These and other product slates (Fischer-Tropsch) have been identified and discussed in Chapters 3 and 4.

Tables 5-10 and 5-11 depict the scenarios constructed from this data. Table 5-12 compares the scenario with other data.

TABLE 5-9 : POTENTIAL COMMERCIAL SCALE PROJECTS--COAL LIQUIDS (12/80)
(SOURCE : E. J. Bentz & Associates; note feasibility study refers only to PL 96-126 programs)

PROJECT	SITE	PROCESS	PROJECT SIZE (1000BOE/D)	EST START UP	APPRQX. COST (B$)
W.R. GRACE STATUS: DOE cost shared demo; conceptual design near completion; construction scheduled for 1984.	TN	Texaco Methanol M-Gas	6		0.5
TEXAS EASTERN SYNFUELS STATUS: Feasibility study completed; entered into cooperative agreement with DOE.	KY	Fischer Tropsch	56		
HAMPSHIRE ENERGY STATUS: Beginning DOE funded feasibility study.	WY	Methanol M-Gas	18	1985	
NAKOTA CO. STATUS: Beginning DOE funded feasibility study.	ND	Methanol	40	1987	
W.R. GRACE STATUS: Beginning DOE funded feasibility study.	CO	Methanol	14	1986	
AMAX STATUS: Beginning DOE funded feasibility study.	MN	Methanol		1985	
HOUSTON NATURAL GAS/TEXACO STATUS: Beginning DOE funded feasibility study.	LA	Methanol	11	1987	
COOK INLET REGION STATUS: Beginning DOE funded feasibility study.	AK	Methanol	23	1987	
CELANESE STATUS: Beginning DOE funded feasibility study.	TX	Methanol	10	1986	
CLARK OIL & REFINING STATUS: Beginning DOE funded feasibility study.	IL	Methanol M-Gas	12	1987	

TABLE 5-lo: <u>COAL LIQUIDS BUILD-UP RATE SCENARIOS : INDIRECT AND DIRECT*</u>

(12/80) (In Plant Units of 50,000 BPD)
of Crude Oil Equivalent

	SCENARIO		1980	1985	1987	1990	1995	2000
INDIRECT	A	Capacity added in period			3	3	3	5
		Total Capacity			3	6	9	14
	B	Capacity added in period			3	5	10	12
		Total Capacity			3	8	18	30
DIRECT	A	Capacity added in period				2	2	2
		Total Capacity				2	4	6
	B	Capacity added in period				2	8	10
		Total Capacity				2	10	20

*Coal liquids build-up scenarios were constructed using interviews and referenced information as cited in Table 5-9, text, and footnotes p and r.

SOURCE: E. J. Bentz & Associates

TABLE 5-11: COAL LIQUIDS BUILD-UP RATE SCENARIOS* (12/80)

(In plant Units of 50,000BPD)
of Crude Oil Equivalent

Scenario		1980	1985	1987	1990	1995	2000
A	Capacity added in period			3	5	5	7
	Total Capacity			3	8	13	20
B	Capacity added in period			3	7	18	22
	Total Capacity			3	10	28	50

*Values derived from Table 5-10.

SOURCE: E. J. Bentz & Associates

TABLE 5-12: COAL LIQUIDS COMPARISONS

(MMBD) of Crude Oil Equivalent

Source	1980	1985	1987	1990	1992	1995	2000
National Energy Plan[1]							.7-1.8
Frost & Sullivan*				1.0-1.5			9.5
U.S. DOE[3]			.14 .12	.5 .37	.8 .57		
She11[4]		.03		.25			
Scenario A			●15	.4		.65	1.0
Scenario B			.15	.5		1.4	2.5

[1]National Energy Plan II, 5/79.

[2]Synfuel Week reported 2/8/80.

[3]Private communication, DOE, 11/80.

[4]Shell National Energy Outlook, Preliminary Version, Feb. 1980.

SOURCE: E. J. Bentz & Associates

(D) Summary Tables and Comparisons

Table 5-13 depicts the summed synthetic fuel deployment schedules. Table 5-14 compares our “grass root” scenario build-up with other estimates developed by different approaches. As seen in Figure 5-1, the scenario brackets most estimates.[s]

Next we will look at the labor requirements associated with the scenarios, as well as identify other impacts and concerns associated with their synfuel deployment.

TABLE 5-13 : SUMMED SYNTHETIC FUEL DEPLOYMENT SCHEDULES*

(in plant units of 50,000 BPD)
of Crude Oil Equivalent

		1980	1985	1990	1995	2000
	Shale Oil	.-	**.5**	**8**	**9**	**9**
	Coal Liquids	--	--	8	13	20
A	Coal Gases	--	1.7	7.11	13.6	18
	Total	--	2.2	23.11	35.6	47
	(MMBD)	--	(.11)	(1.16)	(1.78)	(2.35)
	Shale Oil	--	**.5**	**10**	**18.5**	**19.0**
	Coal Liquids	--	--	10	28	50
B	Coal Gases	--	1.7	13.0	23	30
	Total	--	2.2	33.0	69.5	99
	(MMBD)	--	(.11)	(1.65)	(3.48)	(4.95)

*Derived from adding Tables 5-2, S-7, and 5-ll.

SOURCE: E. J. Bentz & Associates

TABLE 5-14 COMPARISON OF TOTAL SYNTHETIC FUEL PRODUCTION
ESTIMATES (TARGET GOALS)

(MMBD)
of crude Oil Equivalent

Source	1985	1987	1990	1992	1995	2000
Energy Security Act[1]		.5		2.0		
Exxon Outlook[2]			1.2-1.5			4.0-6.1
Bankers Trust[3]			.5			
Mellon Institute[4]						2.1
Natl. Energy[5] Plan (II)						2.4-4.1
NTPSC[6]						
(Low-Meal)	0-.02		03-.18		.28-1.27	1.34-5.34
Shell[7] 2/80	.22		.89			
Scenario A	.11					
Scenario B	.11					

[1]Energy Security Act, PL 96-294 6/30/80, Sec. 100(a)(2).

[2]Exxon Energy Outlook, Dec. 1979.

[3]Bankers Trust Forecast--as reported in Synfuels, 8/15/80.

[4]Mellon Institute Forecast--as reported in Synfuels, 8/22/80.

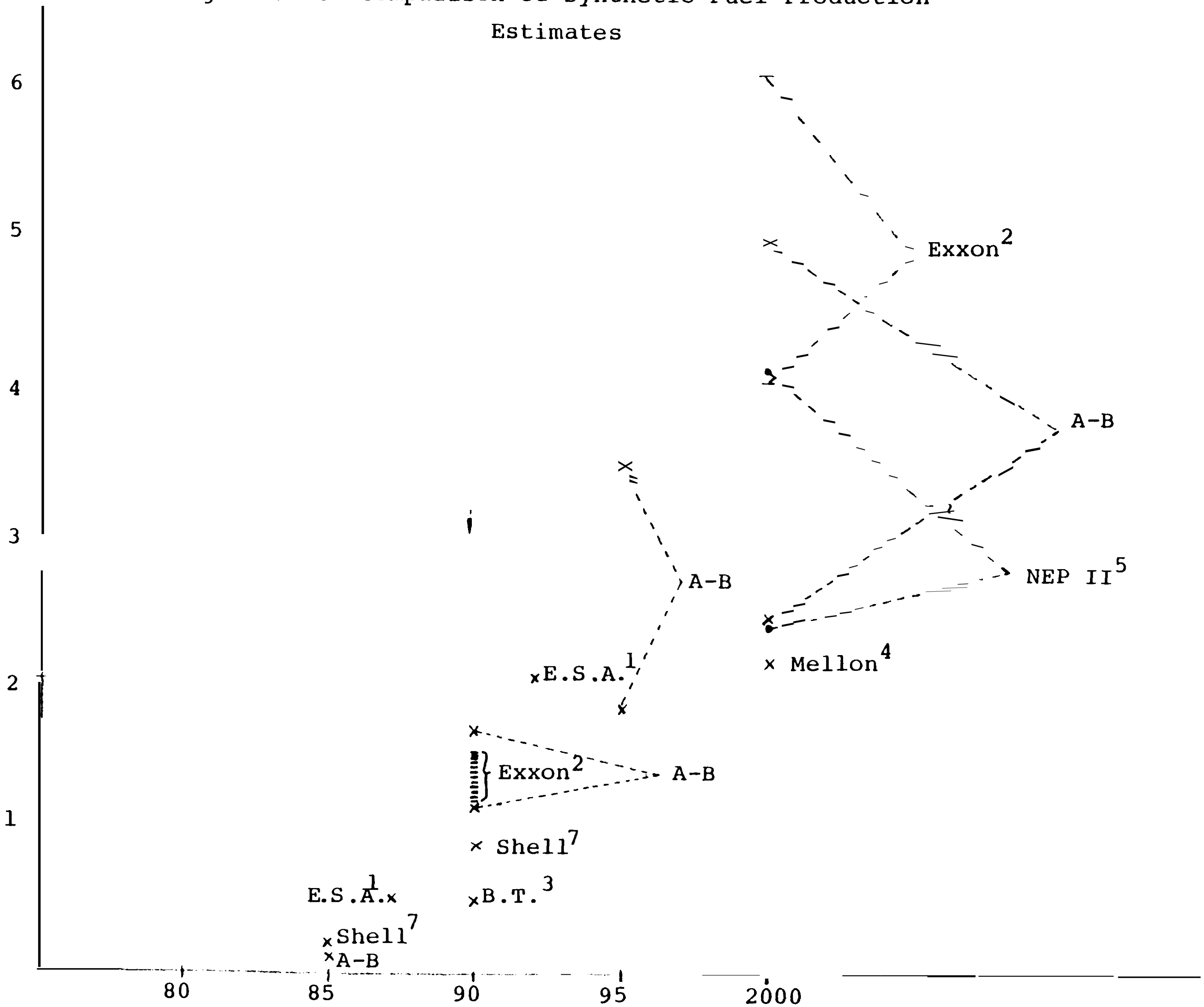
[5]National Energy Plan II, May 1979.

[6]National Transportation Policy Study Commission Report, July 1979.

[7]Shell National Energy Outlook, preliminary version, Feb. 19, 1980.

SOURCE: E. J. Bentz & Associates

Figure 5.1: Comparison of Synthetic Fuel Production Estimates



SOURCE: E. J. Bentz & Associates (derived from Table 5-14)

5.4 Labor Requirements Associated With The Scenarios

There are two categories of labor needs: construction labor and operations labor. As discussed in Chapters 2, 3 and 4, construction labor represents a peak employment situation whereas operations represents a steady-state labor requirement associated with the useful life of the facility. In addition, as discussed earlier, there are additional labor requirements in the geographical (and sectoral) area associated with provision of goods and services for the facility or for its labor force. The peak labor force is confined to a limited number of years (4-6) and often is several times the size of the resident population. This is especially so in the West. The impacts of this surge in peak labor can cause numerous community and environmental concerns in addition to severe strain on local infrastructure and even erosion of this infrastructure. Reference No. 52 discusses in detail some of these site impacts and their consequences. In addition, several studies, such as the Sec. 153a Studies of the 1976 Highway Bill, have looked at "Coal Roads" Issues, and the recently passed Energy Security Act mandates further studies to assess and hopefully suggest mitigation to energy impacted communities. The National Transportation Policy Study Commission in its final report (July 1979) specifically addressed the large and growing impacts of coal movement either in unbeneficiated or product form (pp. 141-149: The Commission forecast a large growth in the movement of coal. Associated with these movements will be: physical capacity concerns of a carrier nature; adequacy of service issues associated with carrier capabilities; and potential disruptions associated with these large scale movements) .

5.4.1 Operations Labor Needs

Based on Chapter 4 results, a typical labor composition for operation of a 50,000 barrel/day synthetic fuel facility is as follows:

Operations	120	people
Operator supervisors	25	people
Maintenance labor	150	people
Maintenance supervisors	30	people
Administrative	30	people
Total	355	people

Hence, upon applying this typical labor force participation to the scenario deployment estimates we arrive at the following aggregate estimate of needs: (See Table 5-15).

TABLE 5-15 AGGREGATE OPERATIONS LABOR NEEDS (WORKERS) *

Workers	1985 A	1985 B	1990 A	1990 B	1995 A	1995 B	2000 A	2000 B
Operators	264	264	2773	3960	4272	8340	5640	11,880
Operator Supervisors	55	55	578	825	890	1738	1175	2,475
Maintenance Labor	330	330	3465	4950	5340	10,425	7050	14,850
Maintenance Supervisors	66	66	693	990	1068	2085	1410	2,970
Administrative	66	66	693	990	1068	2085	1410	2,970
Totals	781	781	8202	11,715	12,638	24,673	16,685	35,145

* Table 5-15 entries derived upon applying Chapter 4 typical labor force estimate to values developed in Table 5-13. Operations labor needs skill mix utilized, Chapter 4, based on ESCOE process estimates.

SOURCE: E. J. Bentz & Associates

5.4.2 Construction Labor Needs

For a typical 50,000 BOED synthetic fuel plant, the following construction labor skill mix needs are representative for the generic process as described in Chapters 3 and 4 (manpower requirements provided by Chapter 4 reference information and Reference No. 53). These estimates, as described in the reference citation, are associated with the conversion process above. In addition to these estimates will have to be added labor needs associated with mining, transportation, potential upgrading, distribution, and retailing. These requirements, however, will depend upon the specific product produced, the particular resource (fuel or coal) selected, the nature of the site, and other specific features. The Appendix to Chapter 2 gives a representative sample for different specific conditions. Manpower rates used are those based upon the previously referenced ESCOE work, which was part of the original study design.

A. Direct Coal Liquids and Shale:

Engineers	958 man years
Draftsmen/Designers	625 man years
Manual, blue collar (including pipefitters, welders, skilled labor)	9160 man years

B. Indirect Coal Liquids:

Engineers	1985 man years
Draftsmen/Designers	1330 man years
Manual, blue collar (including pipefitters, welders, skilled labor)	16,185 man years

C. Coal Gases

Engineers	1000 man years
Draftsmen/Designers	700 man years
Manual, blue collar (including pipefitters, welders, skilled labor)	9000 man years

The typical construction period is spread such that the spread used for construction personnel labor demand is as follows: (This does not include permitting requirements or delays)

% Deployment	Year 1	2	3	4	5
Engineers	30	40	15	10	5
Draftsmen/Designers	30	40	15	10	5
Manual/Blue Collar	o%	10%	30%	40%	20%

Using the above estimates, and the previously derived supply deployment scenarios, we estimate the following incremental labor construction requirements (for each indicated time period) for each generic process and scenario (Tables 5-16 to 5-19).

TABLE 5-16 : DIRECT COAL LIQUIDS*

Incremental Construction Labor Requirements for Plants Coming On-line in Period Ending

(Man-years

	1987		1990		1995		2000	
Scenario:	A	B	A	B	A	B	A	B
Engineers	-	-	1,916	1,916	1,916	7,664	1,916	9,580
Draftsmen/ Designers	-	-	1,250	1,250	1,250	5,000	1,250	6,250
Manual, Blue Collar	-	-	18,320	18,320	18,320	73,280	18,320	91,600

*Table 5-16 values based on process construction labor needs identified in Section 5.4.2 applied to values in Table 5-10.

SOURCE: E. J. Bentz & Associates

TABLE 5-17: INDIRECT COAL LIQUIDS*

Incremental Construction Labor Requirements for Plants Coming On-line in Period Ending

(Man-years)

	1987		1990		1995		2000	
Scenario:	A	B	A	B	A	B	A	B
Engineers	5,955	5,955	5,955	9,925	5,955	19,850	9,925	23,820
Draftsmen/ Designers	3,990	3,990	3,990	6,650	3,990	13,300	6,650	15,960
Manual, Blue Collar	48,555	48,555	48,555	80,925	48,555	161,850	80,925	194,220

*Table 5-17 values based on process construction labor needs identified in Section 5.4.2 applied to values in Table 5-10.

SOURCE: E. J. Bentz & Associates

TABLE 5-18: SHALE OIL*

Incremental Construction Labor Requirements for Plants Coming On-line in Period Ending

Man-Years

	1985		1990		1995		2000	
Scenario:	A	B	A	B	A	B	A	B
Engineers	480	480	7,185	9,100	958	8,143	-	480
Draftsmen/ Designers	313	313	4,688	5,938	625	5,313	-	313
Manual, Blue Collar	4,580	4,580	68,700	87,020	9,160	77,860	-	4,580

*Table 5-18 values based on process construction labor needs identified in Section 5.4.2 applied to values in Table 5-2.

SOURCE: E. J. Bentz & Associates

TABLE 5-19 : COAL GASES *

Incremental Construction Labor Requirements for Plants CominOn-line in Period Ending

(Man-Years)

	1985		1990		1995		2000	
Scenario:	A	B	A	B	A	B	A	B
Engineer	1,700	1,700	5,410	11,330	6,480	10,000	**4,400**	**7,000**
Draftsmen/ Designers	1,190	1,190	3,78+7777	7,910	4,543	7,000	3,080	4,900
Manual, BlueCollar	15,300	15,300	48,690	101,700	58,410	90,000	39,600	63,000

*Table 5-19 values based on process construction labor needs identified in Section 5.4.2 applied to values in Table 5-7.

SOURCE: E. J. Bentz & Associates

5.4.3 Regional Deployment of Synthetic Fuel Plants Work Force

Not all construction labor needs will be uniformly distributed. As discussed earlier, different generic processes will favor siting in different regions:

(i) Oil Shale: Almost all shale plants will be sited in the West until the close of the century. Hence all labor needs--both construction labor and operation labor--will be centered at the sites specified earlier (Piceance, Uinta Basin).

(ii) Coal Liquids: Coal liquids, like coal gases, will be more widely dispersed due to the abundant and regionally varied U.S. coal supplies. As discussed earlier, most of the earlier plants will be of the indirect variety. Later direct plants will be deployed in the Interior and Appalachian regions. Using our previous build-up estimates, and those of other references, (34), we estimate the following regional work force for coal liquids:

Table 5-20: Regional Share of Incremental Construction Work Force for Plants Coming On-Line in Period Endina:

(% Share of Totals in Man Years)[t]

Scenario:	1990 A	1990 B	1995 A	1995 B	2000 A	2000 B
South Atlantic	0	11%	29%	15%	O	6%
East North Central	37%	30%	29%	35%	50%	41%
East South Central	13%	13%	14%	13%	17%	12%
West North Central	25%	21%	14%	15%	o	18%
West South Central	0	0	0	5%	17%	12%
North Mountain	25%	25%	14%	5%	17%	11%

(iii) Coal Gases: As discussed earlier, coal gases' characteristic size units are smaller, more numerous and more regionally dispersed. It is expected that they will share the same regional share deployment as do coal liquids reflecting sitings at coal resources, and reflected in the table above.

5.5 Additional Concerns and Impacts: Product Acceptability Concerns

We have already identified key impact concerns and constraints: associated with synfuel development along the entire fuel cycle (Chapter 2); associated with individual technological processes (Chapter 3); with upgrading (Chapter 4); and with actual proposed synfuel plants (Chapter 50. We also have identified and discussed the supply-oriented needs and constraints associated with synfuel development. Many of these concerns are characteristic of the site-process selection (see Footnote to Chapter 5) , and others are characteristic of the entire industry build-up to meet synfuel objectives.

In addition to these concerns, there are other concerns associated with synfuel product acceptability in the user marketplace. Traditional end use technology--such as internal combustion engines--have been optimized to meet performance specifications based on power fuel specifications, i.e., fuel product specificity must match engine tolerances on a physical and material basis. In addition to these performance specifications, additional institutional requirements have been placed on the utilization of end use technologies. Choosing the automobile again, automotive emission standards for criteria pollutants have been established with scheduled decreases in emissions over time. In addition, automotive fleets are subject to meeting the CAFE standards for fuel economy. Hence the optimization process of matching automotive performance with fuel specifications is a constrained one.

The potential changes in automotive standards (emission standards for diesel exhaust), as well as the potential introduction of new regulations and procedures which impact on fuel production (such as regulations pursuant to TSCA, RCRA, and Hazardous Waste Act) , will further constrain the choices available and the time available to find them. Also in the achievement of these choices, tradeoffs between preservation of performance goals and removal of potential contaminants may have to be made. Several examples of the types and nature of these product acceptability concerns follow:

- Severe hydrotreating of syncrudes may alter or destroy certain fuel characteristics such as lubricity. In recent tests (Reference No. 54 of hydrotreated Alaskan crude, the Navy found that the hydrotreating affected the lubricity of the resulting fuel, which in turn affected the operation of their fuel pumps in aircraft engines.

- The handling and burning of heavy fuel oils, especially from coal, may raise <u>potential</u> concerns due to their high aromaticity and potential toxicity. Potential carcinogenic concerns have also been raised (Reference No. 55). These concerns require further testing.

- Nitrogen removal: Several concerns have been raised about the relatively higher concentration of nitrogen in synfuels. Among them:

    . Higher nitrogen content in synfuels has been found by Navy to be a factor in "gumming" (reference above) .

    . Meeting present NO_x automotive emission standards (1.2 grams/mile) has been difficult for the industry. With the higher fuel-bound nitrogen content of oil shale liquids, this difficulty is expected to increase. Although severe hydrotreating of the oil shale would certainly improve this situation, it would involve, as discussed in Chapter 4, additional upgrading costs. (In general, shale oil would be hydrotreated to reduce nitrogen content prior to pipelining to refinery. Also arsenic contaminants would be removed as-they would poison refinery catalysts, a key question in the degree of upgrading to meet anticipated specs, and at what cost?)

    . Most SRC liquids have been found to be too high in sulfur and nitrogen content. Recent tests sponsored by EPRI at Con-Ed in New York with SRC-II liquids have required combustion modifications.

- The storage of incomplete refined or upgrated products may pose disposal problems (and costs) especially in more fragile ecosystems (see reference 56 for discussion of aggregate waste requirements) .

Next Step(s)

Next Step(s) will require that additional research and testing be performed both at the fuel supplier and end-user levels so that optimum changes can be made between fuel upgrading requirements and end-use combustion changes. As shown in Chapter 4, synfuels can, in principle, be processed to resemble current fuel production "specs" (e.g., gasoline produced from the Sun Oil refinery at Toledo from tar sands feedstocks) . Similarly, redesign of end-use technologies to meet less expensively produced synfuel yields are potential research options.

The potential use of the higher aromatic content of coal liquids for efficiency improvements in higher-compression engines is one example. The use of neat methanol is another. The essential series of sub-optimization "match-ups"--constrained by health, environmental, safety and other concerns such as liability for technology warantees--will also reflect the utilization of current infrastructure (e.g., refinery capacity) , and the projected composition of natural crude supplies (Alaskan and Saudi sour crudes, Venezuelan and Bakersfield heavy crudes; Overthrust production), to which synthetic fuels contribute. This, however, is beyond the scope of this study.

5.6 FOOTNOTES TO CHAPTER 5

a. (i) The general methodology used in developing the "bottoms-up" assessments has used the following sources of information:

(1) referenced literature and data cited in text and footnotes

(2) numerous interviews with industrial and governmental sources, including members of the OTA Synfuel Advisory Group

(3) proprietary information heretofore developed by EJB&A, as cited

*Much of the interview information built upon existing and on-going studies being performed by EJB&A. As such, the data base used was much larger than the study scope allowed in itself. Among the key sources of interview information were:

(1) Governmental interviews were conducted with numerous federal- and state offices including: the U.S. Department of Energy [Policy Office, Fossil Fuel" Office, Resource Applications, Conservation Office, National Laboratories (Oak Ridge)], the U.S. Environmental Protection Agency (Toxics Substance Office, R&D Office), Kentucky Department of Energy; California Energy Commission; and the Massachusetts Energy Office.

(2) Industrial interviews were conducted with numerous staff of the major oil companies; chemical companies; automotive companies; and utility companies.

The OTA Synfuels Advisory Group, as well as the OTA staff, were particularly helpful in their sound advice, judgment, and insights in developing information.

(ii) The overall guiding general assumptions used in the methodological approach were:

(1) There will be no major international conflict which would preclude supply of foreign raw materials and manufactured equipment.

(2) There will be no dramatic increase in the consumption of energy related materials or equipment by other segments of industry which will impact on the synfuels fuels program.

(iii) The overall approach methodology is given in footnote p.

(iv) Specific assumptions associated with the development of each of the scenario assessments have been given in the text, and in footnotes: p (general and for shale oil); q (for coal gases); and r (for coal liquids. Furthermore, regionalization techniques are cited in footnote t.

(v) Scenario scope was chosen in consultation with OTA staff at initial and interim briefings, and as reflected in contract study scope.

b. As discussed later in the individual scenario sections, "high" refers to a maximum deployment schedule, which pushes the limits of material and skill mix availability. However, it does <u>not</u> represent an emergency, supply interruption contingency scenario. Development in the high scenario is conducted by the private sector with fiscal and R&D incentives being provided by the government so as to minimize commercial risk, and to accelerate the pace of development. The "business-as-usual" deployment schedule represents a more historical growth characteristic of capital-intensive new growth industries, as discussed in Chapter 4. High capital demands, technical uncertainties, and other factors discussed in Sections 5.2 and 5.3 dictate a more cautious approach that minimizes financial exposure. The governmental role is mainly an R&D role, especially in high-risk, yet potentially high payoff beneficial technologies. Government fiscal incentives are very minimal as compared to the high scenario. High and low scenario choices were chosen in conjunction with guidance from the OTA staff in initial, and subsequent interim briefings.

c. I.e., in the mid-term (1980-2000), we have attempted using existing information on scheduled supply projects to match supply concerns with demand needs. An aggregate approach reveals little as to the "make-up" of the fuel composition, although macro aggregate techniques can be valuable in long-term analysis, and in investigating macro-economic effects such as capital formation and monetary effects.

d. Post 2000 fuel demand slate requirements are dictated more by an assessment of long-term economic market forces, and post 1980 mid-stream supply corrections that by 1980 "current" supply deployment constraints. This is especially so since there is ample time (for the 2000+ period) to remedy longer-term constraints and because of the inherent uncertainties associated with projecting long-term supply projections. This will be more fully discussed later in footnote p, subsection (v).

e. "Transition period" here simply refers to the time period 1980-2000 in which we are introducing new fuel supply sources to complement our existing sources. Post 2000 fuel supplies may consist of considerable numerous, non-renewable, and renewable fuel sources contributions. As such, the 1980-2000 period reflects a period of decision-making and change to achieve alternate fuel goals.

f. Examples of these are: fuel cell use in automobiles; electric vehicles; and extensive use of active device solar heating and cooling. For a more detailed description of potential automotive end use technology changes see Report of the National Transportation Policy Study Commission, June 1979, p. 93.

g. As an example of an alternate integrated approach see Forecasts of Freight System Demand and Related Research Needs, National Academy of Sciences, June 1978; "Transportation Modeling and Freight Demand Trends," p" 33, E. J. Bentz & Associates

h. Already defined in (e) above.

i. These alternative assessments, as referenced, reflect the use of a variety of different techniques. The specific techniques used differ greatly. Whereas some forecasts rely heavily on the use of macroeconomic models (e.g., DRI, Wharton, Chase) , others use more industry-specific survey approaches. In the cited references for each alternative forecast, the specific methodology employed is identified. It should be clearly recognized that there are no "best and only" approaches, since different technique highlight different effects, e.g. , an industry survey may give good insight on industry-specific technology changes, but give little insight on the impacts of how potential external changes in national interest rates may affect the industry.

j. Capital formation concerns including availability and rate concerns are a key ingredient to synfuel project development. However, scope, budget, and time precluded a discussion of an analysis of these concerns. A general discussion of these concerns can be found in "Synthetic Fuels," Report by the Subcommittee on Synthetic Fuels of the Committee on the Budget, U.S. Senate, September 27, 1979, Chapter IV, p. 23, and Appendix I, p. 55.

k. Exhibits 5.1 and 5.2 identify respectively the potentially critical material and equipment requirements for coal liquid plants (and associated mines), and overall selected material and equipment items required.

They both represent a series of computer runs using the ESPM model described in reference 44. The key implications of these tables and reference 44 are:

- for most equipment items, projected requirements represent a relatively small percentage of overall manufacturing capacity

- in general, domestic manufacturers can expand production as demand develops

- in addition to domestic capacity, there is foreign manufacturing capacity that can supplement U.S. domestic capacity

- there are key items, as discussed above in the text (such as draglines), where there may be a potential constraint of a capacity or leadtime nature

Furthermore, as illustrated in Table 5.2, reference 44 assessed for two different deployment schedules, peak needs for equipment as a function of current production capacity. In this regard" "peak" was used to represent the maximum annual equipment requirements associated with the deployment schedules.- Once again, we see that "draglines" and "heat exchangers" are items of concern in that peak requirements are a significant fraction of existing domestic capacity. These peak concerns are further constrained in that some items such as draglines, air separation plants, and large pumps and reactor vessels require substantial supply leadtimes. Although foreign purchases may alleviate potential shortfalls, early programmatic planning can facilitate domestic manufacturing expansions. These plans would include not only equipment planning but planning concerning: transportation needs, capital formation, siting concerns, water needs, and technical personnel needs. These will be discussed later in text.

l. Overall employment statistics are of limited value in assessing potential labor constraints. The shortages which may occur will be for a particular technical or craft skill. For this reason, exhibits 5.3-5.4 are broken down by skill mix. Similarly, since project construction--as described in later section--is location specific, an overall regional assessment is illustrated in exhibit 5.5. As reference 44 discusses, the key labor constraint concerns are:

- the availability of chemical engineers may be a key limiting factor in the availability of engineering manpower

- the most serious challenge in meeting engineering requirements will probably be in the early peak years, as Exhibit 5.3 shows for design and construction. This simply reflects the early intensive use of these skills in normal project deployment

- that the supply of civil, electrical, industrial, and mechanical engineers will probably not present as severe a concern as meeting chemical engineering requirements (Exhibit 5.3)

- of skilled construction labor needs, the critical needs are those of pipefitters, welders, boiler-makers, and electricians (Exhibit 5.4). For some sparsely settled regions of the nation where there is a limited skilled labor force, this will mean bringing in considerable new labor (such as in the Alaskan pipeline) . Exhibit 5.5 illustrates this regional pattern of potential skilled labor needs.

m. Water supply and availability is of key concern to the siting of synfuel plants. As mentioned in the text (p. 5-13) and in Chapter 2, this is particularly true for arid regions of the West- Under the prevailing system of purchased water rights, most of the available surface water supply in these Western regions has already been allocated. As such, these rights will have to be acquired for prospective projects. It has been estimated in The Nation's Water Resources, the Second National Water Assessment, U.S. Water Resources Council, 'Washington, D.C., vol. A-2, April 1978, that the characteristic maximum water consumption in the most water-scarce areas likely to contain synfuel plants would be about 5% of current consumption. State Water Law in the West: Implications for Energy Development, Los Alamos Scientific Laboratory, January 1979, gives a comprehensive discussion of current water rights, and transfer in the West, especially as they affect potential energy site development.

n. Ranges of shale oil capacity vary greatly depending on key assumptions. As an example, the OTA's "An Assessment of Oil Shale Technology, " June 1980, lists a 1990 production target of 400,000 barrels/day as being "consistent with achieving an efficient and cost-effective energy supply system" (p. 10) and an alternate 1990 production target of 200,000 barrels/day as a target "to maximize ultimate environmental information and production" (p. 11). Similarly, Exxon, in its 1980 Report to the Business Roundtable, lists a target of 8 million barrels/day by the year 2010 in the

Piceance and Uinta Basin. These ranges which depict the uncertainty of many key technical and socioeconomic variables are illustrated in Tables 5-3 and 5-4.

0. As discussed earlier, the determination of site choice for different processes is affected by many factors. There are several critical factors that are common to the siting of any synthetic fuel facility. They have been discussed at length in the literature of both coal and oil shale facilities (Reference Nos. 31, 32 and 33). One such review (Reference No. 32) includes a detailed evaluation of seven representative facilities for various critical factors, which include both physical and institutional aspects. The situations assessed are representative of potential siting situations for coal and oil shale conversion facilities. The critical factors considered are:

- Capital availability
- Industrial marketing decisions such as transportation availability
- Resource depletion
- Air pollution control
- Water availability
- Surface mine reclamation
- Socioeconomic disruption
- ownership of land and the management of federally owned lands

The main objective is to determine on a regional basis the potential for development of a synthetic fuels industry with minimal conflicts. Assessment of the ability to mitigate some of the environmental constraining impacts have been studied (above references) .

Among the characteristics that have been identified and assessed are:

(1) Air Quality Characteristics: Special attention has been paid to constraints due to Prevention of Significant Deterioration and non-attainment areas.

(2) Water Availability: Institutional factors (e.g., competing uses, allocation policies, water rights) as well as physical factors (e.g., stream flows, quality of the water) have been identified.

(3) Socioeconomic Capacity. The capability of communities to adjust successfully to the potential social disturbances associated with the construction and operation of large synthetic fuel facilities have been identified as the key factor in affecting public acceptance. This factor is particularly important for synthetic fuel facilities to be located in western states where the communities are small relative to the size of the facilities. Socioeconomic capacity is evaluated with respect to population size of the affected communities, their infrastructure level of services, and growth history.

(4) Ecological Sensitivity. This factor is evaluated with respect to susceptibility of natural ecosystems to disturbances associated with large scale industrial activity. Waste disposal operations and reclamation of mined lands and disposal sites of spent shales are considered important considerations.

(5) Human Health. There is an undetermined potential risk to both the health of occupational workers employed in the synfuel plants, and to the population surrounding the plants. As discussed in reference 31 , the risk factors are still largely undefined because knowledge is lacking about the kinds and quantities of toxic materials to be released from actual synfuel plants. (See

(6) Land ownership. This factor, and particularly the management of federally owned lands, is particularly important in the West. There, the federal government is a major land holder, and some critical lands are owned by Indians. Policies established under the Federal Land Policy and Management Act of 1976, as well as existing management practices are in conflict with extensive exploration and development of coal and oil shale resources and with the siting of synfuel facilities.

P* Table 5-2 shale oil build-up scenarios were constructed using the following iterative process. This same approach was used in the build-up scenarios of coal liquids and gases:

(1) Utilize General Methodological Assumptions stated in footnote (a) (i.e., not supply interruption concerns) .

(2) Specific Approach:

(i) From Table 5-1 develop initial project schedules baseline reflecting "business-as-usual conditions. In developing baseline schedules utilize specific project information; interviews with industry and government officials and comparisons with other individual and aggregate companions (referenced in Table 5-3)

(ii) After developing initial baseline, iterate by reviewing against above referenced comparisons and additional interviews. Using a modified Delphi-type approval, develop a final baseline schedule.

(iii) using final baseline schedule, repeat steps (i) and (ii) above, under new "upper limit" conditions. These conditions reflect a maximum possible rate-of-growth schedule consistent with pushing material, manpower, and siting concerns discussed in Sections 5.1 and 5.2. They mostly closely reflect an environment of significant governmental fiscal incentives to minimize market commercial risk and accelerate development, as reflected in the economic climate of the fall of 1980. They do, however, reflect utilization of private market forces, and not large-scale direct governmental intervention. For a more detailed discussion of governmental assistance see "Synthetic Fuels, Report of the Senate Budget Committee, September 1979, Chapters IV and V. As such, this "high" scenario does <u>not</u> reflect an emergency planning, oil supply disruption scenario. Such-a scenario, although very useful in its own right, was not in the directed scope of work, and would require significantly different methodological assumptions and techniques.

(iv) After developing a final "high" and "low" scenario, specific scenario characteristics, such as differences in rate of growth, peaking of scheduled outputs, and leveling "off" phenomena were compared to above referenced interviews and literature. A comparison of several of these alternate "scenarios," albeit using different, and mostly proprietary techniques, is given in Table 5-3.

(v) post 2000 deployment schedules are mostly "second-round" decisions which would be based on both results of first round (1980-2000) successes and failures, as well as an assessment of the market needs for synthetic fuels in light of the supply, availability, and price of conventional fuels, as well as end-uses. For these reasons, extreme values (at 2000) reflect first round decisions on deployment, and not second round decisions. As such, they are subject to more uncertainty. A long-term overall energy supply, demand, and price forecast was outside of the scope of this effort. Also, for the numerous uncertainties in Sections 5.1 and 5.2, as well as the technical and methodological uncertainties inherent in long-range forecasting. A discussion of the methodological and data needs associated with long-range energy forecasting is given in Forecasts of Freight System Demand and Related Research Needs, National Academy of Sciences, 1978, p. 33; "Transportation Modeling and Freight Demand Trends," E. J. Bentz & Associates. A discussion of the supply and availability of energy for future transportation needs is given in Alternate Energy Sources, Part B, Academic Press, 1981, p. 733, Transportation and Energy, Outlook to 2000, E. J. Bentz & Associates.

(vi) There are additional product quality and acceptability concerns associated with the use of the synfuel products. These concerns, already introduced in Chapter 4, are discussed in Section 5.4 and accompanying footnote. They add an additional element of uncertainty into the deployment schedule, but at this early research stage are at best difficult to bracket.

q* From Tables 5-5 and 5-6 and referenced literature and interviews, the low/reed Btu and high Btu coal gas build-up scenarios were constructed from Table 5-7, using the iterative methodology described in foot note p, and the general assumptions outlined in footnote a. As discussed in the text (Section B), particular reference 50 was made to the National Coal Association Coal Synfuel Survey reference as well as detailed proprietary information developed by E. J. Bentz & Associates, and numerous private communications with industry and governmental officials (federal and state). As stated on p. 5-24, the eventual regulatory treatment of high Btu gas (pricing, advances to 'pipelines) will greatly affect the scenario schedules. Although the scenarios assured that high Btu gas will be treated as natural gas, this realization will be affected not only by the treatment of high Btu gas, but also on the pricing schedule of natural gas itself (i.e., natural gas deregulation) . Table 5-8 summarizes comparisons with current alternative forecasts. Note, as discussed in footnote p, these alternative forecasts employed a variety of different proprietary methodological techniques. As such "bottoms-up" comparisons are not appropriate.

r. From Table 5-9, and identified literature and interviews, using the iterative methodology described in footnote p, and the general assumptions outlined in footnote a, Table 5-10 was constructed. Of specific assistance were references 50 and 51, as well as proprietary information developed by

E. J. Bentz & Associates, in the deployment schedules. In brief, indirect liquefaction technology is a known, commercially proven technology. Although on-going R&D will improve this technology (such as alternate gasifier designs), it is building upon a known baseline. Also much of the equipment needed is commercially available. As such, early development in the coal liquids area will utilize indirect liquefaction techniques (including the Mobil-M gasoline process) . Direct liquefaction offers great promise, but requires more R&D to achieve a similar commercial-type status. Also, as discussed in Chapter 4, many of the direct products will have to be upgraded, at additional costs, for use in existing end-use technology. Hence, "direct liquids" will be introduced later in our deployment schedules. Because of the variety and complexity of coal liquid sources, as well as the shale oil liquid contribution to our liquid supply (discussed earlier), additional iterations had to be undertaken sequencing individual supply sources (e.g., shale and indirect liquids earlier) and then reiterating the sums against independent numbered comparisons and previous interview results. As such, the "coal liquids" scenarios--high and low--represented the greatest number of iterations. The comparisons of the developed build-up rates with alternate estimates (derived using different proprietary methodologies) is given in Table 5-12.

s. As discussed in footes a, 'p, q, and 5, Table 5-14 depicts alternative macro-estimates developed by the referenced sources using alternate (and often proprietary) techniques.

t. Table 5-20 developed by distributing on regional basis each of the incremental construction work forces for each of the processes, described in Tables 5-16, 5-17, 5-18, 5-19 and then adding regional sums. In tiers, these regional factors were first obtained using following independent sources:

- reference 34 regional factors developed for coal liquids
- Tables 5-1, 5-5, 5-6, and 5-9
- reference 20 for coal liquids (indirect) and reference 6 for all synthetics
- proprietary information developed by E. J. Bentz & Associates

NOTE: It should be noted that Figure 2-3 on p. 2-4 represents the geological coal resource region. Because such a breakdown does not include all supply resources (e.g., shale) as well as the fact that site location is dependent upon a variety of factors (see footnote o), the regions chosen for regionalization were the well-known and used (in all the above references) census regions.

u. An example of the diversity of aromatic chemical properties associated with coal-derived gasoline is given in the following table.

Aromatics (Wt %)	Gasoline from Petroleum	Gasoline from SRC-II Naphtha Hydrotreated	Gasoline from EDS Naphtha Hydrocracked	Gasoline from H-Coal Gas-Oil Heavy Hydrocracking
Benzene	.12	18.0	.08	5.1
Toluene	21.8	19.0	12.6	6.5
Alkyl-benzene C_8-C_{13}	7.0	27.9	43.6	**14.6**

SOURCE: U.S. Environmental Protection Agency, Research Triangle Park, 1980