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

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*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]

	1990		1995		2000	
Scenario:	A	B	A	B	A	B
South Atlantic	o	11%	**29%**	**15%**	**0**	**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 <u>Forecasts of Freight System Demand and Related Research Needs</u>, 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 <u>potentially critical material and equipment requirements for coal</u>

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, boilermakers, 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
Alkylbenzene C_8-C_{13}	7.0	27.9	43.6	**14.6**

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

APPENDICES

APPENDIX TO CHAPTER 2

Typical Mining Characteristics: Tables 3-8
From Reference: “Technology Characterizations”
U.S. DOE, June 1980

TABLE 3 - Surface Coal Mining—Eastern

ENERGY SYSTEM:

SIZE
- 20-year mine life
- 4 million tons per year
- 102.8×10^{12} Btu per year equivalent
- Eastern area mine, Northern Appalachian district

DESCRIPTION
- In the East, modified area mining is generally used in areas where the terrain is gentle (5° to 10° slope) and the overburden does not exceed about 100 feet. Typically, the thickness of the coal bed averages six feet and the efficiency of removal is about 80 percent (in terms of Btu recovered). Blasting with light charge is frequently needed to improve the mining. Overburden from each successive cut is placed in the previous one. Regrading to approximate the original land form is undertaken. Topsoil is replaced and revegetation is begun. Coal is transported to an offsite coal preparation plant.

COMPONENTS	Quantity
• power shovels	3
• trucks	7
• front end loaders	2
• scrapers	4
• coal shovel	2
• drilling equipment	4
• graders	2
• cable handler & reel	2
• bulldozers	8

ENVIRONMENTAL CONCERNS
- aesthetics
- acidic mine drainage contamination of surface and groundwater
- blasting damage and noise pollution
- vehicular emissions
- fugitive dust
- erosion
- altered land use

RESOURCES USED:
(Per 10^{12} Btu Produced)

RESOURCE DEPLETION	
in-place coal	48,438 tons
energy content	12,850 Btu/lb
COAL ANALYSIS	(by weight)
moisture	3.9
volatile matter	34.1
fixed carbon	52.4
ash	9.6
sulfur	2.1
nitrogen	1.1
ENERGY	
diesel fuel	6.0×10^{9} Btu
electricity	5.9×10^{5} kWh
LAND	Acres
fixed	0.3
incremental	6.1
WATER	Acre-Feet
consumption	1.7
COSTS	Dollars (1977)
construction	
total construction cost	1.24×10^{6}
other investments and fees	0.68×10^{6}
operation	
general mining cost	$0.46 \times 10^{+}$
reclamation and sediment control	$3 \times 10^{'}$
PERSONNEL	Workers
construction	
non-manual, technical	1.0
non-manual, non-technical	0.2
manual	4.7
operation	
non-manual, technical	0.8
non-manual, non-technical	1.1
manual	2.4

RESIDUALS (Per 10^{12} Btu Produced)	GROSS (tons)	NET (tons)
AIR POLLUTANTS		
particulates(1)	0.06	0.02
SO_2	0.1	0.1
NO_2	1.5	1.5
hydrocarbons	0.2	0.2
CO	0.9	0.9
WATER POLLUTANTS		
Total Dissolved Solids	35.6	20.8
Iron	0.4	0.0004
Manganese	0.4	0.1
Aluminum	0.6	0.03
Zinc	0.02	0.002
Nickel	0.006	0.002
Sulfate	16.1	14.3
Total Suspended Solids	4.8	0.4
Iron	0.02	0.004
Ammonia	0.06	0.02
SOLID WASTE(2)		
overburden removal	435	0
runoff treatment	390	0

ENERGY PRODUCT
raw coal - 38,910 tons

(1) Assumes a 60% reduction in fugitive dust emissions through dust suppression.
(2) Assumes all solid waste is returned to mining pits.

SOURCES: The MITRE Corporation, Annual Environmental Analysis Report, 1977.
University of Oklahoma, Energy Alternatives: A Comparative Analysis, 1975.
TRW, Mese Environmental Data Book, Volume IV, 1978.
Hittman Associates, Inc., Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use, Volume I, 1974.
Bechtel Corporation, Energy Supply Planning Model, 1978.
Bureau of Mines, Basic Estimated Capital Investment and Operating Costs for Coal Strip Mines, 1976.
Energy and Environmental Analysis, Coal and Profitability, 1979.
Bureau of Land Management, Federal Coal Management Program, Final Environmental Statement, 1979.

TABLE 4 - Surface Coa Min ng—Western

ENERGY SYSTEM:

SIZE
- 6 million tons per year
- 1.1 x 10^{14} Btu per year equivalent
- 30 year mine life
- Western area mine, Powder River Basin

DESCRIPTION:

- In Wyoming and Montana, the two states which will account for most of the increase in production in the West, area strip mining is the dominant surface mining technique. After segregating the topsoil for subsequent reclamation purposes, and after blasting, the overburden (averaging 70 feet) is removed in long parallel cuts. The now exposed and blasted coal seam (averaging 25-30 feet) is removed (89 percent efficiency in terms of Btu recovered). With the exception of the first cut, overburden from each cut is placed in the previous one. Coal is loaded into trucks for transport to a coal cleaning area. Reclamation consists of grading the spoil, replacing the topsoil and initiating revegetation.

COMPONENTS	Quantity
• trucks	11
• front end loaders	2
• scrapers	8
• draglines	2
• bulldozers	12
* drilling equipment	6
* graders	2
* coal shovel	2
• cable handler and reel	2

ENVIRONMENTAL CONCERNS
- fugitive dust and vehicular emissions
- reclamation
- alkaline mine drainage
- erosion
- noise
- aesthetics
- altered land use

RESOURCES USED:
(Per 10^{12} Btu Produced)

RESOURCE DEPLETION	
total in-place coal	59,449 tons
heat content	9,450 Btu/lb
COAL ANALYSIS	**% (by weight)**
moisture	21.5
volatile matter	34.5
fixed carbon	39.6
ash	4.4
sulfur	0.4
nitrogen	1.2
ENERGY	
fuel	0.8 x 10^{9} Btu
electricity	1.1 x 10^{5} kWh
LAND	**Acres**
fixed	0.4
incremental	1.8
WATER	**Acre-Feet**
consumption	3.8
COSTS	**Dollars (1977)**
construction	
total construction cost	1.32 x 10^{6}
other investments and fees	0.23 x 10^{6}
operation	
general mining cost	0.28 x 10^{6}
reclamation and sediment control	2 x 10^{3}
PERSONNEL	**Workers**
construction	
non-manual, technical	1.1
non-manual, non-technical	0.2
manual	2.2
operation	
non-manual, technical	0.7
non-manual, non-technical	0.9
manual	1.9

RESIDUALS
(Per 10^{12} Btu Produced)

	GROSS (Tons)	NET (Tons)
AIR POLLUTANTS		
Particulates(1)	0.2	0.08
SO_2	0.2	0.2
NO	2.0	2.0
hydrocarbons	0.2	0.2
CO	1.2	1.2
WATER POLLUTANTS		
Total Dissolved Solids	90.9	23.9
Iron	0.005	0.005
Manganese	0.02	0.02
Aluminum	0.006	0.006
Zinc	0.005	0.005
Nickel	0.001	0.001
Sulfate	41.1	32.7
Total Suspended Solids	3.0	2.3
Iron	0.002	0.02
Ammonia	0.1	0.2
SOLID WASTE(2)		
overburden removal	745	0
runoff treatment	NA	0

ENERGY PRODUCT
raw coal - 52,910 tons

(1) Assuming 60% reduction in fugitive dust emissions through dust suppression.
(2) Assumes all solid waste is returned to mining pits.

SOURCES: The MITRE Co po on Ana Env onmen Ana
Un Ok homa Com Ana , 1975.
BM En Da
, Environmental Impacts ency, and Cost of Energy Supply and End Use, Volume I, 1974.
ray Supply Planning Mod
1976.
Environmental Statement, 1979.

TABLE 5 -

Underground Coal Mining—Eastern

ENERGY SYSTEM:

SIZE
- 2 million tons per year
- 51.4 x 10^{12} Btu per year equivalent
- 20 year mine life

DESCRIPTION
- The mining involves driving main entries with production entries normal to the main entry on the right and left. As mining advances on one side of the main entry, rooms are excavated in the five foot coal seam. The strata above the seam is supported by pillars of coal. After an entire section is mined, part of the coal in the pillar is recovered (overall, about 57 percent recovery is possible) as a return to the main entry is made. With a mechanized continuous miner, many of the mining operations performed in the same section are executed simultaneously. An electric powered continous miner either bores, digs or rips the coal from the working face. Coal is then loaded into a ratio feeder at the tail piece of a unit belt conveyor.

COMPONENTS	Quantity
• mainline belt conveyor	1
• roof bolting machines	13
• ventilating fan	1
• continuous mining machines	11
• loading machines	11
• shuttle car	22
• ratio feeder	11
• rock duster	12
• supply motor	5
• mainline power center	5
• section rectifier	11
• auxiliary fan	13
• section belt power center	7

ENVIRONMENTAL CONCERNS
- solid waste disposal
- runoff from waste piles
- acid mine drainage
- subsidence of surface area
- noise

RESOURCES USED:
(Per 10^{12} Btu Produced)

RESOURCE DEPLETION	
total in-place coal	68,264 tons
energy content	12,850 Btu/lb
COAL ANALYSIS	**(by weight)**
moisture	3.9
volatile matter	34.1
fixed carbon	52.4
ash	9.6
sulfur	2.1
nitrogen	1.1
ENERGY	**kWh**
electricity	7.2 x 10^5
LAND	**Acres**
fixed	0.3
incremental	11.7
WATER	**Acre-Feet**
consumption	2.3
COSTS	**Dollars (1977)**
construction	
manpower	1.7 x 10^5
material	1.1 x 10^5
equipment	3.8 x 10^5
other investments and fees	7.1 x 10^5
operation	
manpower	4.9 x 10^5
material	0.8 x 10^5
equipment	1.4 x 10^5
other costs	3.6 x 10^5
PERSONNEL	**Workers**
construction	
non-manual, technical	1.3
non-manual, non-technical	0.1
manual	4.3
operation	
non-manual, technical	3.9
non-manual, non-technical	5.2
manual	12.4

RESIDUALS AND PRODUCTS:
(Per 10^{12} Btu Produced)

	GROSS (Tons)	NET (Tons)
AIR POLLUTANTS		
Air emissions from equipment are not considered a problem in underground extraction since most equipment is electric powered.		
particulates	negligible	
SO_2	negligible	
NO	negligible	
hydrocarbons	negligible	
CO	negligible	
aldehydes	negligible	
WATER POLLUTANTS		
Total Dissolved Solids	396.4	392.0
Iron	22.4	0.02
Manganese	0.6	0.2
Aluminum	3.6	1.7
Zinc	0.1	0.02
Nickel	0.06	0.02
Sulfate	197.8	174.9
Strontium	0.2	0.2
Chloride	0.6	12.7
Fluoride	0.1	0.1
Calcium carbonate*	101.7	138.3
Total Suspended Solids	19.0	1.7
Iron	7.0	0.2
Ammonia	1.0	0.3
SOLID WASTE		
from sinking the mine shaft	2.5	2.5
from treating mine water runoff	0	2,090
from extraction process	NA	NA

ENERGY PRODUCT
raw coal - 38,910 tons

*Calcium carbonate net emissions are greater than calcium c bons on ons be um bons ad ad we we as part of the treatment process.

SOURCES: The MITRE Corporation, Annual Environmental Analysis Report, 1977.
University of Oklahoma, Energy Alternatives: A Comparative Analysis, 1975.
TRW, Mass Environmental Data Book, Volume IV, 1978.
Hittman Associates, Inc., Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use, Volume I, 1974
Bechtel Corporation, Energy Supply Planning Model, 1978.
Bureau of Mines, Basic Estimated Capital Investment and Operating Costs for Coal Strip Mines, 1976.
Bureau of Land Management, Federal Coal Management Program, Final Environmental Statement, 1979.

TABLE 6 - Surface Oil Shale Mining

ENERGY SYSTEM:

SIZE
- 73,700 tons of raw shale per day
- 0.413 x 10^{12} Btu/day
- 2,800 Btu/pound of raw shale
- 30 gallons/ton shale oil content
- mine operates 328.5 days/year
- 24.2 x 10^6 tons of shale mined/year
- total annual output is 136.67 x 10^{12} Btu
- mine life is 30 years

DESCRIPTION
- In surface mining, the overburden is removed exposing the underlying shale. Shale is mined using the bench technique. Shale is fractured through drilling and blasting and transported by trucks to primary crushing site.

COMPONENTS
- drilling equipment
- excavation equipment (cranes)
- crushers
- trucks

ENVIRONMENTAL CONCERNS
- air quality deterioration
- noise
- water requirement
- contamination of underground water supplies with saline mine water

RESOURCES USED:
(Per 10^{12} ● IM Produced)

FUEL	Tons
raw unmined shale	178,450

ENERGY	
electricity for operating drilling equipment and trucks	NA

COMPOSITION	% (by weight)
organic material	17.1
water	1.4
inorganic material	81.5

LAND(1)	Acres
mine development	0.8
disposal of permanent overburden	7.4
storage of spent shale	1.1
disposal of spent shale	1.1

WATER	Acres-Feet
mining and crushing	2.8 (2.2 - 3.3)

COSTS	Dollars (1978)
construction(2)	
manpower	226,033
materials	28,809
● Qutpmoat	339,649
● cher cost	14,797
total	609,283
operation & maintenance	NA

PERSONNEL	Workers
construction	NA
operation & maintenance	NA

RESIDUALS AND PRODUCTS:
(Per 10^{12} Btu Produced)

AIR POLLUTANTS	Tons
● artlcdolso	21.79
SO_2	0.21
NO_x	2.95
hydrocarbons	3.44
CO	1.00

WATER POLLUTANTS
probability of ● I 1 O C contamination of underground water by mine water

SOLID WASTE
negligible (.00 Processing)

ENERGY PRODUCT	Tons
mined shale rock	178,450

(1) This represents land committed to use over the lifetime of the plant, divided by the annual output of the plant, expressed in trillion Btu.
(2) This represents total cost of constructing the plant, divided by the annual output of the plant, expressed in trillion Btu.

SOURCES: Environmental Protection Agency, Monitoring Environmental Impacts of the Coal and Oil Shale Industries, 600/7-77-015, February 1977.
Cameron Engineers Incorporated, Synthetic Fuels Handbook, 1975.
Department of Energy, Draft Environmental Impact Statement for the (updated) Prototype Oil Shale Leasing Program, 1979.
University of Oklahoma, Energy Alternatives: A Comparative Analysis, 1975.
Bechtel Corporation, Energy Supply Planning Model, 1978.

TABLE7 - UndergroundOilShale Mining

ENERGY SYSTEM:

SIZE
- 73,700 tons of raw shale per day
- 0.413×10^{12} Btu/day
- 2,800 Btu/pound of raw shale
- 30 gallons/ton shale oil content
- mine operates 328.5 days/year
- 24.2×10^{6} tons of shale mined/year
- total annual output is 135.67×10^{12} Btu
- mine life is 30 years

DESCRIPTION
- Underground mining uses room and pillar technique. The oil shale deposit is entered through a tunnel dug into the side of a valley where an outcrop appears. Pillars are left in place to provide roof support at appropriate intervals. Extraction is also accomplished by drilling and blasting. The broken shale is transported to portable crusher for primary crushing.

COMPONENTS
- drilling equipment
- excavation equipment (cranes)
- crushers
- trucks

ENVIRONMENTAL CONCERNS
- air quality deterioration
- noise
- water requirement
- contamination of underground water supplies with saline mine water

RESOURCES USED:
(Per 10^{12} Btu Produced)

FUEL	Tons
raw mined ● halo	178,450

ENERGY	
electricity for operating drilling equipment and trucks	NA

COMPOSITION	% (by weight)
organic material	17.1
water	1.4
inorganic material	81.5

LAND(1)	Acres
mine development	0.15
crushing	2.93

WATER	Acre-Feet
mining and crushing	2.8 (2.3 - 3.3)

COSTS	Dollars (1978)
construction(2)	
manpower	164,224
materials	43,249
● qulpanc	254,842
other cost	82,341
total	544,655
● Nrttl= & maintenance	NA

PERSONNEL	Workers
construction	484
operation & maintenance	NA

RESIDUALS AND PRODUCTS:
(Per 10^{12} Btu Produced)

AIR POLLUTANTS	Tons
particulates	4.46
SO_2	0.012
NO_x	0.17
hydrocarbons	0.019
CO	0.10

WATER POLLUTANTS
probability of ● dIBO contamination ● r underground water with ● lm4 water

SOLID WASTE
negligible (see Processing)

ENERGY PRODUCT	Tons
● trod ● IM1O rock	178,450

(1) This represents land committed to use over the lifetime of the plant, divided by the annual output of the plant, expressed in trillion Btu.
(2) This represents total cost of constructing the plant, divided by the annual output of the plant, expressed in trillion Btu.

SOURCES:
Environmental Protection Agency, *Monitoring Environmental Impacts of the Coal and Oil Shale Industries*, 600/7-77-015, February, 1977.
Cameron Engineers Incorporated, *Synthetic Fuels Handbook*, 1975.
Department of Energy, *Draft Environmental Impact Statement for the (updated) Prototype Oil Shale Leasing Program*, 1979.
University of Oklahoma, *Energy Alternatives: A Comparative Analysis*, 1975.
Bechtel Corporation, *Energy Supply Planning Model*, 1978

TABLE 8 - Coal Beeneficiation

ENERGY SYSTEM:

SIZE
- Process 2,857,000 tons of run-of-mine (ROM) coal each year to produce 2 million tons of clean coal
- Hourly capacity 950 tons of ROM coal
- Operates 3,000 hours per year, representing ten shifts per week, 230 days per year
- 20 year plant life
- 87.5% efficiency (in terms of Btus)
- yield by weight is 70%

DESCRIPTION
- Coal beneficiation is ● process for upgrading coal prior to its use for metallurgical or utility purposes. The purpose of beneficiation is to remove impurities (i.e. ash and/or sulfur) from raw coal. The degree of beneficiation depends on the type of coal and its ultimate use. The system described on this summary sheet (level E per Phillips et al.) is a relatively intense procedure. It removes more sulfur and ash than most other types of beneficiation, and it is also more costly. The resultant cleaned coal would be used for metallurgical purposes.

COMPONENTS
- scalping screen
- crusher
- rotary be-bar
- vibrator screens
- jigs
- 40uatorlagmtpt
- thickeners
- filters
- concentrating tables ● r hydroclones
- flotation circuits
- thermal drying

ENVIRONMENTAL CONCERNS
- ● articul.t. emissions
- solid waste disposal
- ● wrtaco water contamination from settling pond overflow and/or refuse pile runoff
- possible ground water contamination from ● octllq pond leaching
- noise

RESOURCES USED:
(Per 10^{12} Btu Produced)

FUEL	Tons
run-of-mine (ROM) or raw coal (assuming one ton of ROM coal has an energy content ● 1 11 ● Iltloa Btus per 800)	51,945

ENERGY(1)	
electricity	2.0×10^5 kWh
oil	5.9×10^8 Btu

LAND	Acres(2)
washing plant	0.2
loading facility	1.8
settling pond	2.3

WATER	Acre-Ft.
consumption	3.7

COSTS	Dollars (1976)
construction	4.3×10^5
operation and maintenance	3.2×10^5

PERSONNEL	Workers
construction (1 year)	8.1
operation and maintenance	1.5

RESIDUALS AND PRODUCTS:
(Per 10^{12} Btu Produced)

AIR POLLUTANTS	Tons (Gross)	Tons(3) (Net)
particulates	91	0.9
SO_2	2.7	0.005
NO_x	1.5	0.6
hydrocarbons	1.1	0.1
CO	5.4	0.2

WATER POLLUTANTS	Tons (Gross)	Tons(3) (Net)
total dissolved solids	143	33
iron	0.2	0.007
manganese	0.2	0.03
aluminum	1.1	0.04
zinc	0.04	0.005
nickel	0.01	0.00)
sulfates	98	18
total suspended solids	5,870	0.6
iron	4.6	0.06
ammonia	0.2	0.05

SOLID WASTE	Tons(4)
primary breaking	0
coarse cleaning(5)	2
raw-coal sizing	0
primary cleaning	10,157
froth flotation	5,341
thermal drying	0
breaking 004 ● ltlS@	2
total	15,502

HEAT
little Or none

NOISE
Noise may ● ffoct workers involved in cleaning coal, but there should be little or no adverse impact on receptors near beneficiation PIOO1O.

ENERGY PRODUCT	Tons	Heat Content
cleaned coal	36,360	13,750 Btu/lb

(1) These figures war. calculated assuming an energy content ● f 12,000 btu/lb ● t coal (Hittman, 1974). They ● . ● otlooal averages (assuming an energy ● ftlct=cr ● t 91.3%) and 40 oat ● PQ1? to elaborate (1.... level B) beneficiation in particular.

(2) These coefficients may b. ● ojoct to ● rsor ● laco the data source presented only the fixed amount of land used without ● pecifying the plant's ● n@*l output ● f cool. In calculating these coefficients, it woo ● aoad hero that plant output was the ● x . ● tbac ● paclflo4 in the "size" section ● f this sheet.

(3) These figures ● ro weighted ● oelciaal averages based upon regional coefficients projected by SEAS for 1979. The regional coefficients were weighted la terms ● t Btus used. Each ● f the coefficients shown on this sheet is ● qtrol to total national tons of residual divided by total national Btu output. These figures include residuals from refuse piles ● d the beneficiation process itself. They ● O O W 4 that 80% ● t coal ● r.porotloa plants ● r. closed cycle ● .4 that ● it refuse is treated. An ● tticloacy ● f 90% (in Btus) was ● oau004.

(4) Based on ● ottooal ● verages la ● lttmm.

SOURCES: Phillips, Peter and Paul DeRienzo, "Assessing the Economics of Steam Coal Preparation", Coal Mining and Processing, September, 1977.
DOE and EPA, Engineering/Economic Analysis of Coal Preparation with SO_2 Cleanup Processes, 1978.
Hittman Associates, Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use, 1974.
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