DOE/PETC/TR-90/10
(DE91000942)

**TRANSPORTATION COSTS FOR NEW FUEL FORMS
PRODUCED FROM LOW RANK U.S. COALS**

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September 1990

Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania

UNITED STATES DEPARTMENT OF ENERGY

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Price: Printed Copy A05
Microfiche A01

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Abstract

Transportation costs are estimated for four types of new fuel forms (solid, syncrude, methanol, and slurry) produced from low rank coals found in the lower 48 states of the USA. Nine low rank coal deposits are considered as possible feedstocks for mine mouth processing plants. Transportation modes analyzed include ship/barge, pipelines, rail, and truck. The largest potential market for the new fuel forms is coal-fired utility boilers without emission controls. Lowest cost routes from each of the nine source regions to supply this market are determined.

Syncrudes and solids are generally the lowest cost new fuel form to ship. Syncrudes cost the least to ship when large diameter pipelines are available. In general, transport of any type of new fuel form in ocean-going and Great Lakes vessels is often less expensive than more direct rail and pipeline routes.

All source regions could supply the entire utility market identified with a solid new fuel form at a median shipping cost in the range of \$14-29 per short ton (1988 dollars). Supply regions with the lowest median shipping cost to supply this market are Alabama and Texas (Texas, Louisiana, Arkansas) at \$14 and \$17 per ton, respectively. Median shipping cost for the supply region with the current largest coal production, Powder River (Wyoming, Montana), is \$24 per ton. This median shipping cost represents about 12%-70% of estimated f.o.b. new fuel form product costs, depending on the particular product.

**Transportation Costs for New Fuel Forms
Produced From Low Rank U.S. Coals**

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1. Summary

The present report presents an analysis of transportation costs of new fuel forms produced from low rank coal deposits located in the lower 48 states of the United States of America. Four types of new fuel forms are considered: solid fuels resembling high rank coal; synthetic crudes produced by coal hydrogenation; methanol; and slurry fuels consisting of char and pyrolysis liquids.

Nine low rank coal deposits are identified as potential resources for the new fuel forms.

They are:

1. Northwest - a region containing over 3.5 billion tons of sub-bituminous coal in Washington state,
2. Powder River - a region containing over 75 billion tons of sub-bituminous coal in Montana and Wyoming.
3. Fort Union - a region containing nearly 27 billion tons of lignite in western North Dakota and eastern Montana,
4. South Wyoming - a region containing over two billion tons of sub-bituminous coal in southern Wyoming and northern Colorado,
5. Denver Basin - a region containing over 13 billion tons of sub-bituminous coal in east central Colorado,
6. Rocky Mountain - a region containing over one billion tons of sub-bituminous coal in western Colorado,
7. San Juan Basin - a region containing over 5.5 billion tons of sub-bituminous coal in northwestern New Mexico and northeastern Arizona,
8. Texarla - a region containing over 10.5 billion tons of lignite in Texas, northern Louisiana, and southern Arkansas, and
9. Alabama - a region containing over one billion tons of lignite in west central Alabama.

The principal potential market for new fuel forms from low rank coals is coal-fired utilities in the lower 48 states operating without emission controls. In 1985 this market consisted of 338 power plants hosting 929 boilers that consumed 499 million short tons of coal. For the purposes of the study, the market was organized into 30 demand regions. Half the demand regions contain only power plants sited on navigable waterways; the other half contain only plants not on navigable waterways. Each group of demand regions contains roughly equal numbers of plants and had roughly equal 1985 coal consumption.

New fuel forms are considered to be produced at mine mouth processing plants. For each of the nine source regions, a centroid was identified as the rail hub nearest to or most central to the coal reserves. Similarly, a central city in each of the 30 demand regions was designated a centroid for that region. The first objective of the present study was to determine the lowest cost transportation modes for each type of new fuel form from each source centroid to each demand centroid. After the most economic transportation modes were identified, costs of bulk shipments, e.g. unit train loads, in 1988 dollars per short ton, were estimated for each route.

Possible transportation modes considered in determining lowest cost routes for each type of new fuel form are as follows:

Solid new fuel form	- open hopper car by rail
	- ship/open barge
	- truck
Synthetic crude	- crude pipeline
	- tanker car by rail
	- ship/tanker barge
	- tanker truck
Methanol	- petroleum product pipeline

- tanker car by rail
- ship/tanker barge
- tanker truck

Slurry fuel

- tanker car by rail
- ship/tanker barge
- tanker truck

Mixed transportation modes were allowed and often achieved the lowest total cost.

Transportation costs were estimated from regression equations prepared using rates actually reported in calendar year 1988. Factors included in the analysis were distance shipped, loading/unloading and storage charges.

Results

Lowest cost transportation modes and their estimated costs are given for each of four types of new fuel form, from each of nine source regions, to each of 30 demand regions, for a total of $4 \times 9 \times 30 = 1080$ routes. These results are tabulated in Exhibits 10.1 through 10.9.

Solids and syncrudes are the fuel forms least expensive to ship in general. For solids this is explained by their use of open, relatively low cost rail and barge vessels. For syncrudes, the economies are from ease of transfer between transport modes and the ability to use low cost, large diameter pipelines.

Lowest cost routes for all types of new fuel forms employ ship/barge wherever this mode is available, with the exception of a syncrude where a large diameter pipeline could be used. Where such pipelines are available, they give syncrudes a cost advantage over other types of new fuel forms with respect to transportation. For instance, syncrudes produced in the Alabama or Texarla source regions, well served by crude pipelines, can supply many demand regions at lower transportation costs than for other new fuel forms.

All least cost routes for solid new fuel forms exhibit transportation costs in the range of \$5-70 per ton, and most of the unscrubbed, coal-fired utility market can be accessed for \$25 per ton or less from any of the nine source regions. Median cost for supplying a solid new fuel form to the entire utility market identified is highest for the Northwest supply region at \$29 per ton, and lowest for the Alabama and Texarla regions at \$14 and \$17 per ton, respectively. The supply region with current largest coal production, Powder River, has a median shipping cost of \$24 per ton. Differences in shipping costs among source regions are due to a number of factors including proximity to users and access to ports and pipelines.

To put the transportation costs into perspective, estimates of product costs for several new fuel forms are shown below. Readers will appreciate that since there are few commercial operations at present, the estimates are necessarily approximate. For the lowest cost product, a solid new fuel form, the median transportation cost, \$24/ton, represents about 70% of the f.o.b. product cost. For the highest cost (and most refined) product, methanol, the median transportation cost represents about 12% of the f.o.b. product cost.

**Estimates of F.O.B. Costs (1988\$) of New Fuel Forms Produced
from Low Rank Coals in the Western United States**

	<u>\$/ton</u>	<u>\$/ MM BTU</u>
Solid New Fuel Form	\$31-\$35	\$1.60-\$1.80
Synthetic Crude	\$163-\$200	\$4.25-\$5.20
Methanol	\$180-\$220	\$8.75-\$10.65
Coal-Water Slurry	\$35-\$46	\$2.65-\$3.45

Another way of comparing transportation costs among the nine source regions is to determine, for each demand region, the source region that can supply a given type of new fuel form for the lowest transportation cost. For solid new fuel forms, Alabama is the lowest shipping cost source for 11 demand regions. By this measure, Fort Union and Texarla are second and third best, respectively, being the lowest cost supplier for seven and five demand regions.

2. Introduction

2.A. The Clean Coal Technology Program

The Clean Coal Technology program of the U.S. Department of Energy aids in the development of technologies for burning coal with emission of reduced levels of pollution. Intended markets for the new approaches to coal use are retrofits of existing utility, industrial, and commercial boilers, and also future facilities deriving heat or power from coal. The cost effectiveness of new technologies for using coal cleanly, i.e., their economic competitiveness, is important to DOE.

One approach to making coal use cleaner and more cost effective is to convert it before combustion into a higher value fuel, a new fuel form. The severity of processing used to transform coal to a new fuel form may vary widely. Relatively low severity treatment suffices to drive off physically and chemically bound water from low rank coals, for instance. At the other extreme is gasifying coal and using the resulting synthesis gas to produce liquids. The state of the new fuel produced may be gaseous, liquid, or solid, or some combination in the case of a slurry fuel.

A number of different properties of a new form may make it a superior fuel to the original coal. Improved fuel properties afforded by some processes under development include the following:

- Higher calorific density,
- Lower sulfur content, on a calorific basis,
- Convenience of a gas or liquid fuel,
- Reduced mineral content (solid fuel),
- Increased structural stability (solid fuel), and
- Increased chemical stability during shipment and storage (solid fuel).

Of all the classes of coal found in the U.S., low rank coals (sub-bituminous, lignite) have stimulated the most interest among process developers as feedstock for producing new fuel forms. The interest can be explained by a combination of intrinsic advantages of many low

rank coals and disadvantages to their widespread use as fuel that might yield to relatively low cost treatment. Low mining cost and low sulfur content are the two outstanding advantages. Offsetting these advantages are a number of characteristics of many low rank coals that have impeded their development for wider use domestically and for export. Low calorific content, remoteness from high concentrations of industry and deep-water ports, and rail transportation costs that are high relative to mining costs have been major impediments. Poor transportation and storage properties (excessive dusting, tendency towards spontaneous combustion) have also been marketing deterrents.

Processes for new fuel forms from low rank coals use various approaches to produce low-sulfur fuels with higher energy content and better stability than the feed coal. An important part of the commercialization plan for a new fuel form concerns transportation from the processing plant to facilities where it is consumed or exported. Given the remoteness of many low rank coal deposits from markets, transportation costs are an important determinant of the overall economics.

The present report presents an analysis of transportation costs for solid, liquid and slurry new fuel forms produced from low rank U.S. coals. The analysis is performed from the point of origin of the new fuel forms, assumed to be at mine mouth, to various population centers and deep-water ports in the contiguous 48 states. Transportation of SNG or other gaseous fuels derived from coal has not been treated because there is little question that pipelines would be required for economic long distance transport. By contrast, non-gaseous new fuels from coal not only can take many forms, but it will be seen that they can potentially access multiple modes of transport and alternative routes to a given destination.

2.B. Transportation of New Fuel Forms

The approach used in the present study is to compute shipping costs of coal-derived new fuel forms from potential points of origin to a large number of potential users, coal-fired utility boilers. The points of origin considered are centroids of nine low rank coal deposits located in the contiguous 48 states. Transportation costs were computed from each potential new fuel

form source to a centrally located city in each of 30 demand regions in the lower 48 states. The demand regions were located to encompass 338 power plant sites that host 929 coal-fired boilers operating without flue gas scrubbers in 1985. This set of boilers represents the primary potential retrofit market for new fuel forms. Their consumption of coal in 1985 was 499 million short tons.

The coal-derived fuel forms under consideration include:

- A solid new fuel form,
- A synthetic crude produced by coal hydrogenation,
- Methanol, and
- A slurry fuel consisting of coal-derived char, pyrolysis liquid hydrocarbons, and, optionally, water.

For each of the four types of new fuel form, transportation costs were computed from each of the nine source regions to each of the 30 demand regions. Where multiple modes of transportation exist, e.g. barge, rail, the lowest cost mode or combination of modes was used.

The transportation modes to be considered for each coal-derived fuel type are as follows:

- **Solid new fuel forms:** rail, ship, barge, and truck transportation. It is assumed that where multi-mode combinations can be constructed at lower cost than single mode methods, their use is appropriate,
- **Synthetic crude:** existing crude oil pipelines where possible; rail, ship, barge and/or truck transport elsewhere,
- **Methanol:** existing crude and/or petroleum product pipelines where possible; rail, ship, barge, and/or truck elsewhere, and
- **Coal/pyrolysis liquid/water slurries:** rail, ship, barge, and/or truck.

It was assumed that the appropriate volume for calculation of transportation rates should be sufficiently large to capture economies of scale where available, e.g., unit train rates for coal shipment. It has therefore been assumed that all fuel forms will be shipped in annual

volumes of at least one million tons, i.e., at least 100 10,000 short ton unit-train loads per year.

3. Study Design: Regionalization of Demand and Supply

As mentioned above, national demand was "lumped" into 30 demand regions, each represented by a single consumption point or "centroid". The supply of new fuel forms from low rank coal was modeled as nine supply regions, represented by regional production/shipping "centroids". Thus, for each type of fuel product there were 9x30 or 270 routes, and for all four product types a total of 1080 potential routes were constructed. Prices were estimated for each of these routes, many of which involve two, three, or -- rarely --four transportation modes. Estimated prices include costs for transportation services, storage (of liquid fuels at the beginning and end of pipeline transport) and loading and transloading of liquids and solids.

3.A. Supply Regions

The nine supply regions used to locate low-rank coal reserves have been selected to focus on reserves with present production or for which production capacity was planned in the 1979-1981 period when f.o.b. mine coal prices were higher than at present. During this period numerous new coal mines were planned that were not constructed due to the subsequent decline in coal prices. These nine regions thus contain the low rank coal reserves that are minable now or in the foreseeable future. Each is briefly discussed below, and all are shown in Exhibit 1.

Northwest: This region contains bituminous and sub-bituminous coal reserves that have been mined in three subregions, all of which lie between the coast range and the Cascade Mountains in Washington state: Issaquah-Grand Ridge, Kelso-Castle Rock, and the Centralia-Chehalis Area. These three areas contain over 3.5 billion tons of sub-bituminous coal reserves, and lie within the Puget Sound lowland adjacent to the Burlington Northern and Union Pacific railroads. The supply centroid selected for this region is Centralia, WA.

Exhibit 1. Supply Regions and Centroids

1. NORTHWEST (Centralia, WA)
2. POWDER RIVER (Gillette, WY)
3. FORT UNION (Bismarck, ND)
4. SO WYOMING (Rock Springs, WY)
5. DENVER BASIN (Denver, CO)
6. ROCKY MTN. (Dotsero, CO)
7. SAN JUAN (Gallup, NM)
8. TEXARLA (Longview, TX)
9. ALABAMA (York, AL)

Powder River: This region contains the sub-bituminous reserves of Montana and Wyoming: The North Central and Bull Mountain Regions of Montana, the Powder River Basin in Montana and Wyoming, and the Big Horn and Wind River Basins in Wyoming. Current coal production is dominated by large surface mines along the Burlington Northern and Chicago and North Western railroads in Wyoming and southeastern Montana. The Burlington Northern and Chicago and North Western railways also serve the Green River and Wind River Basins of central Wyoming. The Burlington Northern crosses the North Central Montana region from east to west, adjacent to that area's limited sub-bituminous reserves. The Montana Rail Link provides access to the Bull Mountain coal field. The Powder River subregion alone contains 57.5 billion tons of sub-bituminous coal reserves, while the Big Horn Basin contains an additional 18.6 million tons of coal reserves. Reserves in the other areas are not yet accurately known, but are substantial. The centroid for this region is at the center of current mining activity, Gillette, WY.

Fort Union: This region contains strippable reserves of nearly 27.0 billion tons of lignite in western North Dakota and eastern Montana. Mining activity is present in Richland County Montana as well as many areas in North Dakota, but is most important in four North Dakota counties: Bowman, McLean, Mercer and Oliver. These last three counties lie immediately northwest of Bismarck, the production centroid for this region. Railroad service is provided by the Burlington Northern and the Soo Line.

South Wyoming: This region combines five areas of strippable sub-bituminous coal reserves in southern Wyoming and Northern Colorado, all of which are connected to external markets by the Union Pacific railroad's east-west line across southern Wyoming. These areas contain more than two billion tons of strippable reserves in the Hams Fork, Green River, Hanna Basin and Rock Creek areas of southern Wyoming and the North Park coal field in north central Colorado. Current production is scattered throughout these areas, but is less than it was in the early 1980s. The centroid for this region is Rock Springs, WY.

Denver Basin: This region underlies metropolitan Denver and lands to the north, south and

east. The Denver Basin contains over 13 billion tons of strippable sub-bituminous coal and lignite in Weld, Boulder, Morgan, Adams, Arapahoe, Elbert and El Paso counties. Lying adjacent to the communities of Denver, Fort Greeley, Boulder, and Colorado Springs, this area has unusually good rail service by western standards. Both the Union Pacific and Burlington Northern railroads connect it to the upper mid-western and eastern states via Chicago. The Denver & Rio Grande Western connects via Salt Lake City with the western states from Los Angeles to Seattle, while the Atcheson, Topeka and Santa Fe railroad connects to points in New Mexico, Texas and the Gulf Coast. This area is also served by the Missouri Pacific, Cadillac & Lake City and Kyle railroads. The centroid for this region is the major rail junction, Denver.

Rocky Mountain: This region consists of two widely separated mining areas in western Colorado that are served by the Denver and Rio Grande Western Railroad. These are the Grand Mesa coal field, or that portion of its southern end that contains sub-bituminous coal (Delta and Montrose counties), and the southeastern tip of the Green River Basin in Routt and Moffat counties. Neither of these areas is large or important in terms of low-rank coal production today. The only well defined coal reserves are about a billion tons in Routt and Moffat counties. The physical isolation of these areas has tended to restrict the market for low rank coals produced here. The only access to the area is by three Denver & Rio Grande Western railroad lines that reach, respectively, Salt Lake City, Denver, and Pueblo, Colorado. In each of these directions, more easily accessible or higher rank coal is available closer to major markets. The bituminous coal fields of central Utah lie between the Rocky Mountain region and Salt Lake City. The Denver Basin is much closer to the Denver market and the Raton Mesa bituminous coal field lies closer to Pueblo. As a result, past exploitation of coal reserves in the Rocky Mountain area has focussed on the higher rank coals of the area. The centroid for this region is Dotsero, on the Denver and Rio Grande Western Railroad.

The San Juan Basin: The San Juan Basin covers the northwestern corner of New Mexico and contains over 5.5 billion tons of strippable reserves of sub-bituminous coal. For the purposes of this report, it includes northeast Arizona's Black Mesa coal fields which are

isolated from class I¹ rail service, but connected to Southern California Edison's Mohave power plant by a coal slurry pipeline, and to the Salt River Project's Navajo power plant by a private electrified railroad. Much of the San Juan Basin in New Mexico is isolated from commercial rail service so that most of the region's present and prospective production is from the area around Gallup, New Mexico, where a spur has been built from the main east-west line of the Atcheson, Topeka and Santa Fe railroad to serve surface mines north of the railway. Since all coal leaving this region moves through Gallup, New Mexico, this town was selected as the transportation centroid for this region.

Texarla: Lignite exists in discontinuous beds of minable thickness and extent throughout much of the Texas coastal plain from San Antonio through Texarkana, TX and Shreveport, LA. These lignite reserves further underlie much of northern Louisiana and southeastern Arkansas. To date most mining activity has been within a triangle defined by Dallas, TX, Shreveport, LA, and Little Rock, AR. Within this area, numerous mines serve minehead or nearby power plants. In Arkansas, lignite has been extracted in Jefferson and Saline counties in connection with the area's bauxite mining industry. Strippable lignite reserves in Texas, Louisiana and Arkansas have been estimated at 10.5 billion tons, but further exploration is likely to add substantial amounts to this total. Most of this region is well served by railroads. It is connected to Tulsa and Kansas City in the north by the Kansas City Southern railroad, to Fort Worth and Dallas by the Missouri Pacific and the Atcheson, Topeka and Santa Fe railroads, and to the Houston-Port Arthur-Lake Charles area by the Missouri Pacific, Southern Pacific, Kansas City Southern, and Atcheson, Topeka and Santa Fe. Access to markets east of the Mississippi River is provided by the Saint Louis Southwestern and Missouri Pacific railroads via St. Louis and Memphis and to the gulf coast and southeastern states by the Mid South railway via Vicksburg. This region lies just to the north of the Corpus Christi-Lake Charles area, one of the largest oil refining centers in the world, and is thus close to many of

¹ Class I railroads are defined by attainment of a minimum level of annual operating revenue. The required amount of revenue changes each year, but was \$92 million in 1988. There are currently 14 Class I railroads. There are also 476 smaller Class II and Class III railroads.

the most important crude oil and product pipelines in the 48 contiguous states. For transportation purposes, the centroid has been placed at Longview, TX.

Alabama: Lignite reserves are known to underlie large areas of central Alabama, Mississippi and Western Tennessee. However, much of the known resources are of poor quality or are contained in thin, discontinuous beds. The only known area with deposits of sufficient extent, quality, and thickness to support large scale mining underlies portions of Sumter, Choctaw, Clarke, Marengo, and Wilcox counties in west-central Alabama. This area contains reserves in excess of 1.1 billion tons, and is served by the Burlington-Northern Railroad, the Norfolk Southern railroad and has access to the CSXT railroad via the Meridian and Bigbee railroad. The area is also served by pipeline. The Colonial and Plantation product pipelines that serve many east coast states run directly through this region to the Washington, DC and New York City areas. This region is also within a short truck haul of barge transportation. The town of York, AL is the transportation centroid for this area.

3.B. Demand Regions

In order to provide typical transportation routes to coal fired power plants, the 48 contiguous states have been divided into 30 regions. These areas were selected based on the distribution of power plant sites and access to transportation routes. Several of the western regions, while large in geographic area, contain only two or three coal-fired power plants. The Northwest region contains only two: Portland General Electric's Boardman plant, and Pacific Power and Light's Centralia, WA plant. Since the Centralia plant is located at the supply centroid for the Northwest supply region, the demand region's centroid was placed at the Boardman plant, on the Columbia River.

Half of the demand regions have been designed to provide minimum cost access to 177 coal-fired power plants that can be reached via navigable waterways. These 177 plants consumed 253 million short tons of coal in 1985, about half that of the total data set of unscrubbed, coal-fired boilers. The remaining 161 plants not on navigable waterways consumed 245 million short tons. A large proportion of the coal-fired power plants located along the

Atlantic and Gulf coasts are situated on waterways that provide sufficient water depth to allow direct access by smaller ocean going tankers and colliers (we have assumed accessibility by ships of up to 30,000 dead weight tons displacement).² In some cases, individual power plants are located adjacent to water of sufficient depth to accommodate vessels of the maximum displacement that can transit the Panama Canal, about 65,000 dwt.

Similarly, there are a large number of plant sites on the shores of the Great Lakes. Since most of the fuel forms under consideration will be produced in or near western U.S. coal fields, a combination of rail or pipeline and Great Lakes vessel transportation (abbreviated GLV in the attached database) can provide economical access to these plant sites in many cases. The only difficulty in reaching these sites stems from the lack of suitable terminal facilities along the Great Lakes. A terminal equipped to load solid fuels onto Great Lakes vessels is located at Superior, WI. There are no commercial tanker terminals on the Great Lakes.

The majority of water-accessible coal plant sites are located along the inland waterway system - the Ohio and Mississippi Rivers and their navigable tributaries. Many of these plants, as well as a large proportion of the plant sites along the Atlantic, Gulf and Great Lakes coasts, have existing dock facilities for unloading barge shipments of solid fuels. Most could provide unloading and storage for liquid fuels at relatively low costs, and the cost of construction of dock facilities for solid fuels would not be prohibitive for plants with a life expectancy of 10 to 20 years.

The cost of water transport tends to be volatile, whether for barge navigation on inland waterways or for vessels on the Great Lakes or oceans. The two primary factors affecting these prices are changes in fleet capacity utilization and changes in fuel price levels. The prices used in the attached data base reflect average conditions during calendar 1988.

²Ocean going bulk cargo vessels of less than about 35,000 dwt cargo capacity are referred to as "handy-sized" vessels. See also page 50.

Half of the demand centroids used have been designed to simulate transportation prices to power plant sites not accessible by water, while the other half were constructed to deal exclusively with sites on navigable water. These two groups of regions are distinct subsets, and centroids for these regions may appear to be puzzlingly close until one recalls that they have been designed to show accessibility by a variety of transport modes from a variety of regions. No attempt has been made to create regions of equal geographic area. The regions containing plants accessible by water are only linear strips of river, lake and ocean shoreline. Nor do the regions contain equal numbers of power plant sites, or equal electrical generating capacity. Because avenues of low cost water transportation may penetrate far into a region that other transport modes can penetrate only at much higher cost, this analysis will show some apparently anomalous patterns of transportation cost. Consider the supply region centroid in Centralia, WA. Transportation costs by rail or pipeline to the trans-Mississippi River eastern U.S. are prohibitive. However, rail transportation of solid and liquid fuels to marine terminals in Vancouver, British Columbia (for bulk solids) or Portland, Oregon (for liquids) allows ocean shipment to the east coast of the U.S., via the Panama Canal, for less than \$20 per ton. It is often the case that an indirect route using the least expensive transport mode provides the most economical alternative. Exhibit 2 shows the relative location of the demand regional centroids; Exhibit 3 lists the demand regions, their centroids, approximate contents, coal-fired generating capacity, and 1985 power plant coal consumption.

Many of the crude and product pipelines that are most conveniently located to allow economical transport of new fuel forms are of small diameter, and therefore compare unfavorably with rail or water transport for the purposes of this exercise. With some exceptions it is found that pipelines work best as a means of bringing fuels to locations where they can be transloaded onto barges, Great Lakes vessels, or ships for delivery to the desired demand centroid. Considerable effort has been made to locate supply and demand centroids close to usable pipelines, and all supply region centroids are located on class I railroad lines.

Exhibit 2. Demand Region Centroids

Exhibit 3: Demand Regions, Centroids and Regional Content

Region	Regional Centroid	# of Sites	Total Capacity (MW) ¹	1985 Coal Consumption (1000 Short Tons) ¹	Regional Content
1	Albany, NY	10	2,255	2,672	NY, VT, NH, ME, MA, CT, RI.
2	Chester, PA	12	6,828	14,475	Eastern PA & MD, NJ, DE.
3	Hamilton, OH	44	34,306	50,150	OH, IN, MI, WV, western PA & MD, VA.
4	Atlanta, GA	39	35,644	58,359	Eastern VA, NC, SC, GA, FL, AL, TN, eastern MS.
5	Joliet, IL	14	7,948	12,369	IL, eastern WI, eastern MO.
6	Houston, TX	18	17,482	31,893	LA, eastern TX, southern AR, western MS.
7	Sweetwater, TX	2	1,800	2,379	West TX excluding panhandle, southeastern quarter of NM.
8	Tulsa, OK	15	11,756	20,039	Oklahoma (excluding panhandle), northern AR, western and southern MO.
9	La Junta, CO	10	4,427	11,473	Eastern CO, western KS, panhandles of OK and TX, northeastern quarter of NM.
10	Sioux Falls, SD	28	13,187	17,837	ND, SD, NE, MN, IA, western WI.
11	Phoenix, AZ	8	9,405	5,920	AZ, western NM.
12	Salt Lake City, UT	12	11,090	4,550	UT, western CO, southern WY.
13	Billings, MT	4	3,546	4,989	ID, MT, northern Wyoming.
14	Bakersfield, CA	5	2,769	2,609	CA, NV.
15	Boardman, OR	2	1,890	5,709	WA, OR.
16	Jersey City, NJ	21	11,776	18,879	Atlantic Coast from Portsmouth NH to Portsmouth VA, Chesapeake Bay.
17	Burnside, LA	6	5,797	9,369	Gulf Intercoastal Waterway, Mississippi River below Vicksburg, MS, Red River below Shreveport, LA.
18	Demopolis, AL	8	10,787	17,325	Mobile, Tombigbee, Black Warrior Rivers, Tenn-Tom Waterway, Tennessee River above Pickwick, MS.
19	White Bluff, AR	3	4,407	9,951	Lower Mississippi River between Memphis and Vicksburg, Arkansas River.

Exhibit 3: Demand Regions, Centroids and Regional Content
(continued)

Region	Regional Centroid	# of Sites	Total Capacity (MW) ¹	1985 Coal Consumption (1000 Short Tons) ¹	Regional Content
20	Cairo, IL	5	5,267	10,605	Mississippi River from St. Louis, MO to Memphis, TN, Kaskaskia River below New Athens, IL
21	Independence, MO	13	9,389	19,143	Missouri River below Sioux City, IA
22	East Peoria, IL	11	7,782	8,967	Illinois Waterway, Chicago to Grafton, IL
23	Alma, WI	9	3,265	6,098	Upper Mississippi River from Minneapolis to Dubuque, IA, Minnesota River, St. Croix River
24	Niota, IL	3	986	2,167	Upper Mississippi River from St. Louis to Dubuque, IA
25	Harbor Beach, MI	7	2,157	3,946	Lake Superior, Lake Huron, Lake Michigan north of Green Bay, WI
26	Milwaukee, WI	13	9,468	16,081	Lake Michigan south of Green Bay, WI
27	Hawesville, KY	24	23,076	43,608	Lower Ohio River below Cincinnati, OH, Green River, Cumberland River, Kentucky River, Tennessee River below Pickwick, MS
28	Lorain, OH	17	29,738	50,403	Lake St. Clair, St. Clair River, Detroit River, Lake Erie, Niagara River
29	Willow Is., WV	25	13,876	23,834	Upper Ohio River from Pittsburgh, PA to Cincinnati, OH, Monongahela, Allegheny, Kanawha Rivers
30	Port Wentworth, GA	12	10,976	12,891	Atlantic Coast from Portsmouth, VA to Key West, FL, Gulf Coast from Key West to Crystal River, FL

¹Coal-fired capacity and coal consumption of generating plants with capacity greater than 100 MW.

3.C. Technical Feasibility Issues

The coal-derived fuel forms under analysis are, if not technically novel, at least unprecedented as large scale fuels for coal-fired utility boilers. It is therefore appropriate to consider technical issues and problems that may restrict the availability of certain modes of transportation for such products. These issues can be categorized as either: 1) definitely prohibiting the transport of certain fuel forms via certain transport modes, or 2) presenting hypothetical problems whose outcome is unknown due to lack of information about large scale transport of these fuel forms by specific modes. Some of these issues are discussed below. In general, where little data exists, it has been assumed that, for the purposes of this analysis, it is preferable to adopt an optimistic point of view. Potential problems are noted, but it has been assumed that they are not unsolvable, although cost penalties for resolving them are not addressed.

A case in point is the rail transportation of solid new fuel forms such as coal-pyrolysis char. Solid carbon fuels are subject to slacking and potentially, spontaneous combustion, upon exposure to air and moisture. Bituminous coal and anthracite present few problems even when stockpiled for several months. Much western sub-bituminous coal is pyrophoric and presents a more serious spontaneous combustion hazard. However, millions of tons of western sub-bituminous coal have been shipped to power plants as far east as Indiana and Ohio. Some coal has been shipped by rail from eastern Wyoming to the Ohio River where it was unloaded, stockpiled, and then shipped up to 650 miles upriver, by barge, where it was again stockpiled at the point of consumption. Lignites, with higher moisture content than sub-bituminous coals, present more serious challenges. They are usually consumed within a few miles of the mine site, although instances exist where they may be shipped up to 500 miles prior to consumption. Long distance transportation of lignite is technically feasible, but requires additional protective measures whose costs cannot be justified given the low heating value, and hence low economic value of lignite fuels. Of course, mitigation of such problems is one of the principal driving forces for developing new fuel forms.

An equally serious issue is the form in which char fuels are transported. If the char is in the form of fine dry granules, it may present an intractable handling problem. Coal transportation technology is not designed to handle large quantities of fine material. The presence of a small percentage of "fines" in coal is inevitable, but creates handling problems in the existing technology. Rail transport of material that is dominantly fine dust-like matter would require containerization, an entirely different and more expensive technology than that used to transport coal to utilities. Thus the issue in transporting pyrolysis char by rail is not the technical feasibility of transporting the char, but whether the value of the char would justify the additional cost of protection from wind and rain. Of course, until the physical and chemical properties of the char are known, it is not possible to estimate either its value as a boiler fuel or its reactivity. It is likely that large-scale transportation of such char will be less of a problem than stockpiling the material at utility sites. It is to be noted that some processes for producing solid new fuel forms employ steps to limit the amount of fines in the product. For the purposes of this analysis, it is assumed that the solid new fuel form can be transported at costs comparable to those for sub-bituminous coal.

There is little reason to doubt the feasibility of transporting coal-derived synthetic crude in existing crude oil pipelines, or for that matter, by barge, rail or truck. Barge and rail rates are slightly higher than those for coal since barges and rail cars for liquid hydrocarbons are double-skinned and covered. Modern practice is to interconnect trainloads of tanker cars containing the same product so that they can be loaded or unloaded by accessing a single car. Liquids are inherently less expensive to load and unload than are bulk solids and the unit cost of moving a ton of product by rail, barge or truck is the same regardless of its liquid or solid state -- once the cost of the container and loading/unloading costs are excluded.

Setting aside the economics of production, it is technically feasible to transport a synthetic crude as a boiler fuel. A major drawback in such an application is that crude pipelines run from producing fields or marine terminals to refineries. Only occasionally do they pass the site of a coal-fired utility boiler, and very infrequently is there a crude-pipeline terminal near a coal boiler site. Distribution of syncrude to coal boilers therefore almost universally

requires a storage facility and a secondary transportation mode to reach a power plant site. Pipelines are also one-way streets. Syncrude or other products can move along the pipeline only in the direction mandated by the flow of liquids that constitute the major portion of the pipeline's burden.

Methanol transportation by pipeline is subject to serious technical feasibility questions. Methanol is more corrosive than water and is also soluble in water. Small batches of methanol may scavenge enough moisture from a pipeline to require redistillation at the downstream end. Larger batches are unlikely to be significantly diluted but may prove unacceptably corrosive. Transmission of small batches of methanol in crude pipelines has been successfully carried out, however, and it has been seriously proposed to ship emulsions of heavy crude in natural gas-based methanol in the Alaska pipeline when existing light crude reserves are exhausted.³ Because the feasibility of methanol transportation in non-dedicated pipelines is an undecided issue, it has been assumed that it will ultimately be found to be feasible. In recognition of the difficulty of pipelining methanol due to its corrosive potential, this study has assumed that only product, not crude, pipelines may be used for this purpose. Because product pipelines have smaller diameter and are less conveniently routed, this decision has the effect of assessing a cost penalty to pipelining methanol compared to syncrude. No other adjustments were made in computing costs of transporting methanol.

Another issue of pipeline use in shipping coal-derived liquids to coal fired utility boilers is that of multiple pipeline use, especially where pipeline maps indicate that such a shipment could proceed part way in a crude pipeline and then be shipped further via a second crude or product pipeline. Inter-pipeline transfers would require product storage between the pipelines in question. While one such storage and transfer might occasionally prove feasible (given that storage facilities exist and are appropriate for the product in question) repeated transfer

³S.S. Marsden "The Transportation of Prudhoe Bay Natural Gas and Heavier Crude Oils to Market." Proceedings of the Alaskan Gas Utilization Workshop, pp. 114-118 Fairbanks, AK: State of Alaska, University of Alaska and U.S. Department of Energy, Office of Fossil Energy, September, 1987.

from one pipeline to another, like repeated transfers from rail to barge to rail, are seldom economically feasible. Any shipper attempting such a strategy would soon find that the handling costs, plus the fixed costs for initiating movement on a pipeline, would nullify any apparent savings from reduced mileage. Most long distance transfer modes charge rates in the form of fixed plus variable, or distance-related costs. The fixed cost charge for initiating transportation is often the equivalent of the variable cost charge for several hundreds of miles; shortcuts seldom save money.

Several technical issues affect pipeline transportation of coal or coal-derived solids slurried in pyrolysis liquids and/or water. Aside from the danger of corrosion of the pipeline by water or other chemicals, the certainty of pipeline pump abrasion by solids renders this alternative unfeasible except for dedicated slurry pipelines. At present only one such pipeline is in operation. This 273 mile pipeline has been in operation since 1970, and has an annual capacity of over 5 million tons. This pipeline connects Peabody Coal Co's Black Mesa Mine in northeastern Arizona to Southern California Edison's Mohave plant in the southernmost part of Nevada. The success of this coal slurry pipeline led to many proposals to build similar lines in both the eastern and western United States during the 1970's and early 1980's.

Due to legal issues concerning access to water and unsuccessful attempts to gain rights-of-way across railroad lines none of these proposed pipelines has reached the construction stage. Any single coal slurry pipeline proposed for the purposes of this analysis could be provided with estimates of engineering costs, but not with credible estimates of legal costs or any plausible estimate of the time when it would be available. Therefore, coal slurry pipelines have not been considered as a viable transportation alternative in this study. Coal or coal-derived solids slurry transportation is thus restricted to rail, barge and truck transportation.

To summarize the above, this study estimates costs for:

- Transportation of solid new fuel forms in unit-train loads in open hopper cars by rail, and open barge and truck,

- Transporting coal-derived synthetic crude by crude pipeline, by tanker-car unit trains, by tank-barge and by tanker truck,
- Transporting coal-derived methanol by petroleum product pipelines, by tanker-car unit trains, by tank-barge, and by tanker truck,
- Transporting coal slurried in pyrolysis hydrocarbons and/or, optionally, water by tanker-car unit trains, by tank-barge and by tanker truck.

In most cases the novel nature of the products being shipped, in combination with the large volumes of product, and the use of transport modes not previously used for large volumes of these products combine to suggest that technical feasibility problems are likely to arise, and that if they do, they will impose additional transportation costs. In the absence of data defining the precise physicochemical nature of these products, it is difficult to estimate these costs.

3.D. Overview of Rate Estimation Methods

Transportation rates used in this study are, with one exception, derived from equations of the form:

- $ax+b=c$, or
- $ax=c$

where a = a variable cost factor,

x = shipment distance in statute miles

b = a fixed cost factor

c = the service price for the shipment in question.⁴

The single exception is the equation used to estimate prices for ocean shipping, which is of a more complicated form. In all cases, the equations used to develop rates were derived by

⁴All rate estimation equations except those for rail, ocean and Great Lakes vessels have been derived from Cardullo, Mario, Transportation of Energy: Today and Tomorrow, forthcoming, McGrawHill, Inc.

linear regression analysis of rates actually reported during calendar year 1988. A detailed discussion of the equations used, and their derivations, is provided in Appendix C to this report. Loading, unloading and storage charges were also obtained for actual cases in 1988.

Because the routes used in this report have never been used for the types of product discussed, all must be viewed as hypothetical. It is not normal business practice to estimate transportation charges for commodities whose physical and chemical properties are not known. Nonetheless, the rates and prices derived for the work reported here are as realistic as can be provided under the circumstances. Readers should note that transportation service prices are volatile, especially for water transportation, and that the cost of water transportation relative to other modes is likely to vary significantly over short periods of time.

4. Results

To review, the present study has identified least cost transportation routes for new fuel forms between nine supply centroids and 30 demand centroids. It has done this for each of four types of new fuel forms (solid, syncrude, methanol, and coal/liquid slurry). Four modes of transportation were considered: crude and product pipelines; ship and barge; rail; and truck. Transportation costs, in 1988 dollars per short ton, have been estimated for large volume shipments in every case for a total of 1080 cases.

A detailed record was prepared for each transportation route, many of which are multimodal, including service prices for transport, loading, transloading (and intermodal storage where necessary) for each link or modal segment of the route.

A complete listing of computed transportation costs is given in Exhibits 10.1 through 10.9 organized by supply region. For each route the primary transportation mode is listed. Also shown is the 1985 coal consumption by demand region for all coal-fired utilities without scrubbers. This gives some idea of the potential market for new fuel forms. With these tables it is possible to estimate the transportation cost for any type of new fuel form between

any pair of supply and demand regions.

The data in these exhibits have been analyzed to uncover noteworthy characteristics of transportation costs and to show some approaches to organizing the data. As will be evident, the treatment is not exhaustive. We have reviewed the data in three ways. The first is to compare the effect of type of new fuel form on transportation cost, where all four types are considered for the same origin and destination. As will be seen, the relative costs of shipping the four types of new fuel forms order differently depending on the dominant mode of transport employed.

The second and third reviews of the data compare costs for transporting a particular type of new fuel form from various sources to a given destination. In this type of comparison, one of two points of view can be taken: that of the supplier or that of the user. In the following discussion, we illustrate both. In the second review of the data, the distribution of shipping costs to supply the 1985 unscrubbed utility coal consumers with a solid new fuel form is examined. This is done from the point of view of the supplier, in that each supply region is considered in turn. In the third review of the data, lowest cost routes (among all nine supply regions) for each new fuel form type are identified for each demand region. This illustrates the user's point of view.

Effect of New Fuel Form Type on Transportation Costs

In this section we will briefly outline the transportation costs to all demand regions from each supply region so that the reader can gain an overview of the comparative advantages of shipping different fuel forms from a given site. We will also provide a summary of the transportation costs involved to give a general indication of the competitiveness of these costs.

For the Alabama supply region there are four cases (demand regions 4, 9, 12 and 15) where solids would constitute the least expensive fuel form to ship. Despite the fact that no crude pipeline connects the Alabama supply region with 16 of the 30 demand regions, syncrude

shipped by crude pipelines is the most economical fuel form to ship to demand regions 1, 2, 3, 5, 6, 7, 8, 10, 11, 13 and 14. Methanol may be shipped by product pipeline less expensively than other fuel forms to demand regions 17, 18, 28 and 30. In the remaining 11 demand regions, a combination of truck and water transport for all liquid fuel forms is the least expensive fuel/transport mode combination. For demand regions 25 and 26 this involves short truck hauls, barge, ocean vessel and Great Lakes vessel routes (smaller ocean vessels can use the Great Lakes routes if they can transit the locks on the Welland Canal). Demand region 16 can be reached by a combination of truck, barge and ocean vessel, while demand regions 17 through 24, 27 and 29 require truck and river barge combinations.

From the Denver Basin supply region, 20 demand regions can be least expensively reached by solid fuels. In 14 cases (regions 1, 2, 4, 6, 7, 8, 9, 10, 11, 15, 21, 25, 29 and 30) the preferred mode of transport is by rail. In the remaining six cases, savings may be possible by initiating transport by rail, then completing the shipment via river barge (demand regions 17, 18, 19, 20, 23 and 24). In the remaining 10 cases the most economical fuel form to ship is syncrude. The most favorable mode is by pipeline to regions 3, 5, 12, 13, 14 and 16. Pipeline transport must be augmented by truck to complete shipment to regions 26 and 28, and by barge to region 27. In general, shipment from the Denver Basin is more expensive than from Alabama.

From the Fort Union supply region solid fuel forms are least expensively delivered to 28 of 30 demand regions. In the remaining regions (numbers 20 and 22), the competition is very close; methanol shipments by pipeline augmented by barge are cheaper than solid fuel forms by only a few cents per ton, a difference that is less than the margin of error for the price estimates used in this study. Shipments of solid fuels to demand regions 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14 and 15 are by rail. Shipments to demand regions 6, 18, 19, 20, 21, 22, 23, 24, 27 and 29 are begun by rail but completed by barge. Shipments to the remaining regions (16, 17, 25, 27, 28 and 30) are begun by rail and completed by ship and Great Lakes vessel.

The Northwest supply region is disadvantaged by a lack of crude pipelines connecting it to

other sections of the country, and to the liquid fuel terminal in Portland, Oregon. In 15 of 30 cases, the most economically transportable fuel form is methanol. Had a crude pipeline existed to connect Portland, Oregon with the supply centroid (Centralia, Washington) it is likely that syncrudes could have been shipped to these 18 regions at least as cheaply as methanol. In any case, a combination of product pipeline and ocean tanker provides lowest cost access to demand regions 16, 17 and 30. Augmented by freshwater barge, this combination provides lowest cost access to regions 18, 19, 20, 21, 22, 23, 24, 27 and 29. A pipeline/tanker/Great Lakes vessel (or small ocean-going tanker) combination provides lowest cost access to regions 25, 26 and 28.

From the Powder River region, the availability of crude pipelines makes syncrude the least expensive fuel form to ship to 21 of 30 demand regions. In seven cases (demand regions 3, 5, 6, 8, 11, 12 and 21) pipelines alone are required. In nine cases shipments begun by pipeline must be completed by freshwater barge (demand regions 17, 18, 19, 20, 22, 24, 27, 29 and 30) and in one case (region 16) an ocean vessel must also be used. In four other cases routes relying on pipelines must be completed with short truck hauls (regions 14, 25, 26 and 28). In the nine other cases, the most inexpensive fuel form is a solid, and in eight of these nine (regions 1, 2, 4, 7, 9, 10, 13 and 23) the shipment is by rail. The remaining shipment (to region 15) can be made by truck.

From the Rocky Mountain region, the absence of water transportation and rail transport makes rail transport of solid fuel forms the most economical fuel/transport mode in 28 of 30 cases. In 15 of these 28, railroad shipment alone is sufficient (to demand regions 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 21), while in nine other cases the shipment begins by rail and is completed by freshwater barge (demand regions 17, 18, 19, 20, 22, 23, 24, 27 and 29). Shipments begun by rail are completed by Great Lakes vessel to regions 25 and 26, and Great Lakes vessel and ocean vessel to region 16. Shipments to region 30 begin by rail and continue by freshwater barge and ocean vessel. The two regions not reached most economically by solid fuel forms are least expensive for syncrudes. However, syncrudes must be trucked over 100 miles to a pipeline to reach region 3, and a combination of rail, pipeline

and truck must be used to reach region 28. Due to the lack of convenient waterways and pipelines, these shipments are relatively expensive.

Nineteen of the demand regions can be reached at least expense by rail shipments of solid fuels from the San Juan supply region. Of these, eight require only unimodal rail shipments (demand regions 4, 9, 10, 11, 12, 13, 15 and 21) while two require completion by ocean vessel (demand regions 16 and 30) and nine more require both rail and barge (regions 17, 18, 19, 20, 22, 23, 24, 27 and 29). The remaining 11 regions are most economically supplied by syncrudes via pipeline (regions 1, 2, 3, 5, 6, 7, 8, 14) or by combinations of crude pipelines and trucking (regions 25, 26 and 28).

The South Wyoming region can ship solid fuel forms most economically to 17 demand regions. In 12 cases direct shipment by rail is most efficient (regions 2, 4, 6, 7, 8, 9, 10, 11, 12, 14, 15 and 17) while in six others rail is augmented by barge (demand regions 19, 20, 23, 24, 27 and 29). The remaining 12 demand regions are most efficiently reached by syncrude shipments originating on crude pipelines. In five cases these shipments are terminated on pipelines (regions 3, 5, 13, 16 and 21) while in three other cases final delivery is by truck (25, 26 and 28). In two cases delivery is completed by freshwater barge (regions 18 and 22) and in one case by rail (region 1). A single case exists where shipments originate by pipeline, continue by barge and terminate by ocean vessel (to region 30).

The Texasla region lies farther east astride major crude pipelines and close to the Intercoastal waterway and several salt-water ports (Port Arthur, Houston, New Orleans). It therefore experiences low costs for transporting syncrudes to a large number of demand regions. Crude pipelines provide the dominant method of shipment origination, although shipment completion may involve other modes. Only 6 routes originate other than by pipeline, all of which originate and deliver solid fuel forms by rail (to regions 4, 9, 10, 12, 13 and 15). The 24 regions most economically served by syncrude shipments originating in crude pipelines include six terminating on pipelines (regions 3, 5, 6, 7, 8 and 14) and ten terminating by barge (regions 17, 18, 19, 20, 21, 22, 23, 24, 27 and 29). Four others terminate by short

truck hauls (regions 11, 25, 26 and 28) while two more terminate with ocean tanker haulage (to regions 16 and 30). Finally the route to region 1 terminates with a rail haul.

The reader may have noted that methanol is seldom the lowest cost fuel form to ship. Generally speaking, where product pipelines are available to ship methanol, either larger diameter, lower cost crude pipelines make syncrudes the more economical fuel to ship, or if crude pipelines are not available rail or barge shipment of solid fuel forms is less expensive. Wherever water transportation is available for liquid fuel forms, it competes --often successfully-- with pipeline transportation by all but the largest diameter pipelines. While few previous analyses have considered it, transportation in handy-size tankers and Great Lakes tankers is often less expensive than more direct rail and pipeline routes for liquid fuel forms. With respect to transportation, the Alabama and Texas supply regions, relatively close to many eastern and Mississippi Valley demand regions via water or pipeline transport, appear to be promising sites for syncrude manufacture, while the northern supply regions, Powder River and Fort Union, may prove to be most promising for the production of solid fuel forms to be shipped to upper midwestern demand regions.

Distribution of Shipping Costs to Supply Unscrubbed Utility Coal Consumption With a Solid New Fuel Form

Exhibits 11.1 through 11.9 show distributions of shipping costs for solid new fuel forms for each supply region. In the exhibits, each column represents the tonnage of coal consumed in 1985 by unscrubbed coal-fired utilities that could be supplied for a particular shipping cost. Utilities that are situated on navigable waterways are shown separately from those that are not.

All shipping costs fall in the range \$5-10 to \$65-70 per ton, with a concentration of shipping costs in the narrower range of \$15-20 to \$30-35. With typical F.O.B. minemouth costs for subbituminous coal and lignite falling in the range \$10-20 per ton, shipping costs would represent a large fraction of delivered cost of a solid new fuel form.

Median values of shipping costs shown in Exhibits 11.1 through 11.9 are presented in Exhibit 12, and from these values several observations can be made. It is seen that for a particular supply region, neither type of power plant location (on/off navigable waterway) has consistently lower transportation cost than the other. This result does not imply that land-based and water-based transportation modes have roughly equal cost for the same route. Examination of Exhibits 10.1 to 10.9 shows that the lowest cost shipping mode to plants on navigable waterways invariably employs ships or barges. Rather the result implies that on average, the plants on waterways are more distant from most supply regions than land-locked plants. A notable exception to the pattern of roughly equal transportation costs to the two types of plant sites is given by Supply Region 1, the Northwest. For this region, the median shipping cost to plants on waterways is \$11 less. The reason for this large difference is that from the Northwest, transportation costs to land-locked plants are the highest of all supply regions because of its remoteness from most users. For transportation by water, however, the median cost for shipping to plants on waterways from the Northwest is no greater than from some other supply regions.

Supply regions 3 and 5 (Fort Union and Denver Basin, respectively) in the Western plains have lower transportation costs than supply regions farther west, to which they are adjacent. The latter consist of Supply Regions 2, 4, 6 and 7 (See Exhibit 1). The lower costs for the supply regions in the plains are due to their relative proximity to Eastern markets.

The supply regions from which solid new fuel forms could be shipped to most utilities at lowest cost are those in the South, Texas and Alabama, regions 8 and 9. Transportation costs from these two regions to both types of plant sites (on/off navigable waterway) are lower than for any other supply region. Their low costs are due to a combination of proximity to Eastern markets, and access to water transportation and rail systems. The cost advantage for shipping a solid new fuel form from these two regions is substantial, being in the range \$4-15 per ton lower than from the other supply regions.

Comparison of Supply Regions: Lowest Cost Routes

The supply region for which transportation cost of a new fuel form is lowest has been determined for each demand region and for each of the four types of new fuel forms. The results answer a user's question: from which supply region could I get a particular new fuel form for the lowest shipping cost.

The results are tabulated in Exhibit 4. For each demand region and for each type of new fuel form, the supply region with lowest shipping cost is listed. Also given are the shipping cost and the primary mode of transportation.

In the case of solid new fuel forms, nearly two-thirds of all lowest cost routes originate in two supply regions--Alabama and Fort Union. Only one other supply region, Texarla, provides lowest cost routes to more than two demand regions. Lowest cost transportation routes for these three supply regions are shown graphically in Exhibits 5, 6, and 7. The routes beginning in Fort Union supply region provide lowest cost access to the demand regions numbered 1, 2, 10, 23, 25, 26, and 28. Regions 1 and 2 are in the middle Atlantic states, New York state and Pennsylvania, while region 10 is the demand region that encompasses the Fort Union supply region. Region 23 is centered on the upper Mississippi River at Alma, WI, while regions 25, 26 and 28 are located along the shores of the Great Lakes. The routes employed assume rail shipment to the longitude of eastern Minnesota, shipment on Great Lakes vessels to power plants along the lake shores and rail shipment to demand centers further east. The rates estimated for these routes range from \$8.84 per short ton for region 10 (Sioux Falls, SD) to \$26.31 for region 2 (Chester, PA).

Exhibit 4 - Estimated Least Cost Supply Region/Demand Region Transport Routes by Fuel Form

Demand Region	Solid Fuel Forms			Syncrude Fuel Forms			Methanol			Coal Slurry		
	Supply Region	\$/Short Ton	Primary Mode	Supply Region	\$/Short Ton	Primary Mode	Supply Region	\$/Short Ton	Primary Mode	Supply Region	\$/Short Ton	Primary Mode
1	Fl Union	25.09	Rail	Alabama	13.03	Pipeline	Fl Union	55.64	Rail	Fl Union	55.64	Rail
2	Fl Union	26.31	Rail	Alabama	13.03	Pipeline	Alabama	45.66	Pipeline	Alabama	54.59	Rail
3	Alabama	15.35	Rail	Texas	6.62	Pipeline	Alabama	27.59	Rail	Alabama	27.59	Rail
4	Alabama	9.81	Rail	Alabama	14.94	Rail	Alabama	11.44	Pipeline	Alabama	14.94	Rail
5	Alabama	15.71	Rail	Alabama	10.38	Pipeline	Alabama	24.30	Rail	Alabama	24.30	Rail
6	Texas	6.45	Rail	Texas	3.10	Pipeline	Texas	11.87	Rail	Texas	11.87	Rail
7	Texas	7.94	Rail	Texas	5.74	Pipeline	Texas	15.04	Rail	Texas	15.04	Rail
8	Texas	8.25	Rail	Texas	5.50	Pipeline	Texas	15.90	Rail	Texas	15.90	Rail
9	Denver Basin	5.99	Rail	Denver Basin	9.61	Rail	Denver Basin	7.44	Pipeline	Denver Basin	9.61	Rail
10	Fl Union	8.84	Rail	Fl Union	19.53	Rail	Fl Union	19.53	Rail	Fl Union	19.53	Rail
11	San Juan	10.63	Rail	San Juan	12.29	Pipeline	Powder R.	4.17	Pipeline	San Juan	18.94	Rail
12	So. Wyoming	6.51	Rail	So. Wyoming	3.23	Pipeline	So. Wyoming	11.07	Rail	So. Wyoming	11.07	Rail
13	Powder R.	7.68	Rail	Powder R.	9.20	Pipeline	Powder R.	11.53	Rail	Powder R.	11.53	Rail
14	San Juan	12.09	Rail	San Juan	5.91	Pipeline	Powder R.	4.17	Pipeline	Rocky Mountain	16.55	Rail
15	No. West	6.80	Rail	No. West	11.87	Rail	No. West	11.87	Rail	No. West	11.87	Rail
16	Texas	11.95	Rail/Ship	Texas	8.86	Pipe/Barge	Alabama	10.03	Truck/Barge/Ship	Alabama	10.03	Truck/Barge/Ship
17	Alabama	10.96	Rail/Ship	Alabama	9.13	Rail/Barge	Alabama	2.60	Pipeline	Alabama	9.13	Rail/Barge
18	Alabama	6.53	Rail/Barge	Alabama	4.29	Rail/Barge	Alabama	2.29	Pipeline	Alabama	4.29	Rail/Barge
19	Alabama	11.92	Truck/Barge	Alabama	10.85	Truck/Barge	Alabama	10.85	Truck/Barge	Alabama	10.85	Truck/Barge
20	Alabama	9.29	Truck/Barge	Alabama	8.36	Truck/Barge	Alabama	8.36	Truck/Barge	Alabama	8.36	Truck/Barge

Exhibit 4 - Estimated Least Cost Supply Region/Demand Region Transport Routes by Fuel Form
(continued)

Demand Region	Solid Fuel Forms				Syncrude Fuel Forms				Methanol				Coal Slurry			
	Supply Region	\$/Short Ton	Primary Mode		Supply Region	\$/Short Ton	Primary Mode		Supply Region	\$/Short Ton	Primary Mode		Supply Region	\$/Short Ton	Primary Mode	
21	Denver Basin	11.12	Rail		Powder R.	7.41	Pipeline		Alabama	14.47	Truck/Barge		Alabama	14.47	Truck/Barge	
22	Alabama	11.57	Truck/Barge		Alabama	11.02	Truck/Barge		Alabama	11.92	Truck/Barge		Alabama	11.02	Truck/Barge	
23	FL Union	11.01	Rail/Barge		Alabama	13.63	Truck/Barge		Alabama	13.63	Truck/Barge		Alabama	13.63	Truck/Barge	
24	Alabama	11.60	Truck/Barge		Alabama	11.06	Truck/Barge		Alabama	11.06	Truck/Barge		Alabama	11.06	Truck/Barge	
25	FL Union	14.76	Rail/GLV		Texas	16.81	Pipe/Truck		Alabama	17.92	Truck/Barge/Ship/GLV		Alabama	17.92	Truck/Barge/Ship/GLV	
26	FL Union	15.25	Rail/GLV		Texas	15.64	Pipeline		Alabama	19.23	Truck/Barge/Ship/GLV		Alabama	19.23	Truck/Barge/Ship/GLV	
27	Alabama	10.22	Truck/Barge		Alabama	9.44	Truck/Barge		Alabama	9.44	Truck/Barge		Alabama	9.44	Truck/Barge	
28	FL Union	15.44	Rail/GLV		Texas	15.55	Pipeline		Alabama	17.16	Pipeline		Alabama	17.24	Barge/Ship/GLV	
29	Alabama	13.63	Truck/Barge		Alabama	13.42	Truck/Barge		Alabama	13.42	Truck/Barge		Alabama	13.42	Truck/Barge	
30	Texas	11.15	Rail/Ship		Texas	8.04	Pipeline		Alabama	6.24	Pipeline		Alabama	9.21	Truck/Barge	

Exhibit 5. Demand Regions for Which Lowest Transportation Costs are from Fort Union Supply Region (Solid New Fuel Form)

Exhibit 6. Demand Regions for which Lowest Transportation Costs are from Texarla Supply Region (Solid New Fuel Form)

Exhibit 7. Demand Regions for which Lowest Transportation Costs are from Alabama Supply Region (Solid New Fuel Form)

In 11 other cases, the Alabama supply region has the lowest transport costs. These cases are regions 3, 4, 5, 17, 18, 19, 20, 22, 24, 27 and 29. Region 3 is centered in western Ohio, while region 4 is centered in Atlanta, GA, and region 5 at Joliet, IL. These three regions are accessed by rail shipments at estimated rates of from \$9.81 to \$15.71 per short ton. Regions 17, 18, 19 and 20 are all in the mid-south and are accessed by freshwater barge at rates estimated from \$6.53 to \$11.92 per short ton. Regions 22 and 24 are further north on the upper Mississippi and Illinois waterways and regions 27 and 29 are on the Ohio River. Estimated rates from Alabama to these points vary from \$10.22 per short ton to \$13.63 per short ton.

The Texarla region, including gulf coastal Texas, Louisiana and southeastern Arkansas provides the lowest cost routes to regions 6, 7, 8, 16 and 30. Demand region 6 is approximately identical to the southwestern part of the Texarla supply region, while regions 7 and 8 are immediately west and north, respectively, and within easy rail range. Region 16 is centered at Jersey City, NJ and region 30 at Port Wentworth, GA. Access to these ports, at prices estimated between \$11 and \$12 per short ton, is provided by marine shipment on handy-sized ocean-going colliers via Port Arthur, TX.

The remaining 7 demand regions are best accessed by routes from five supply regions. They represent the division of the geographically large but volumetrically small western U.S. market among the sub-bituminous and lignite producing supply regions closest to them.

Implications of Distribution of Lowest Cost Routes

There are some important conclusions in the above general evidence. First, the important eastern and mid-continent market areas are least expensively accessed (for solid fuels) by the closest supply regions: the Fort Union, Texarla and Alabama supply regions. Secondly, the ability to access these areas at feasible levels of transport cost is very largely provided by the use of water transportation:

- Marine vessels from the Gulf Coast to the Atlantic Coast,

- Great Lakes vessels from the Fort Union Basin to the northern Midwest and the interior Northeast, and
- Fresh water barge to points on the Tennessee-Tombigbee, Ohio and Mississippi Rivers and their navigable tributaries in the mid-continent area.

The pattern of lowest cost transportation routes for liquid fuel forms is more difficult to summarize because route costs have been estimated for three modes. These include the rail, water, truck, and ship routes used for solid fuels, but with the caveat that the necessity of using double hulled containers increases shipping costs, while handling costs for liquids are generally lower than for solids. The net result is usually slightly higher rates for liquids than for solids over the same routes. In many cases effective competition to double-hulled container transport of liquids is provided by pipeline--either for syncrude or refined products (such as methanol-type fuels). Thus liquid fuels must be divided into two categories, syncrude and product. Pipeline transport costs, where available, must be compared with and possibly supplemented by transport in containers--tank cars and trucks, tanker vessels and barges.

Transportation of syncrude-type fuel forms is dominated by the low costs from the Alabama and Texarla regions. Those familiar with the geographic routing of large diameter crude pipelines moving petroleum northeastward from the Texas and Louisiana coastal areas will not be surprised to learn that once these pipelines are assumed to be accessible for syncrude movements, they become the lowest cost routes from Alabama to regions 1, 2 and 5 (the mid-Atlantic states and northern Illinois), and from the Texarla region to demand regions 3, 6, 7, 8, 26 and 28. Region 3 is west central Ohio, region 6 the Texas gulf coast, while regions 7 and 8 are west Texas and Oklahoma, respectively, Region 26 is centered on Milwaukee. These routes are priced between \$5.50 and \$16.00 per short ton, varying directly with distance from the supply regions. Many other demand regions can be most economically reached via non-pipeline modes. Region 4 (centered on Atlanta, GA) is readily reached by rail from Alabama for just under \$15.00 per short ton, while regions 17 and 18 in Alabama and Louisiana are accessed by a rail/freshwater barge combination at \$9.00 per short ton, plus or minus a few percent. Regions 19, 20, 22, 23, 24, 27 and 29, representing the entire

Mississippi and Ohio River valleys are most economically reached by truck/barge combinations via the Tennessee--Tombigbee waterway, the Gulf intercostal waterway and the Tennessee, Mississippi and Ohio Rivers (and their tributaries) at prices estimated to fall between \$8.36 and \$13.63 per short ton. Combinations of modes including truck, pipeline and barge provide the Texarla region with lowest transport costs to demand regions 16, 25 and 30. Note that it is less expensive to ship liquids to regions 16 and 30 by pipeline than by marine vessel, which was the least cost mode for solid fuel forms. However, just as was the case for solid new fuel forms, the remaining eight demand regions in the western U.S. experience lowest transport cost from six western supply regions.

Methanol has been assumed to be ineligible for shipment through crude pipelines, but suitable for shipment in product pipelines. Here again, in the absence of pipelines, shipment in tankers, tank trucks, tanker vessels and barges is the method of choice. Because product pipelines are smaller in diameter and less conveniently routed, pipeline transport is usually more expensive than alternative methods. Because of the importance of water transportation (freshwater barge, marine vessel and Great Lakes vessel), the Alabama supply region dominates the analysis providing least cost access to 19 of the 30 demand regions. Truck and barge transport provide access to regions 19 through 24, 27 and 29 at rates in the range of \$8.00 to \$15.00 per short ton. Using barge shipment to Mobile and transloading onto handy-size tanker vessels, liquid fuel forms can be carried by sea to Sept Isles (Province of Quebec), then shipped through all the Great Lakes except Superior by small ocean going or Great Lakes vessels, thus providing access to regions 16, 25 and 26. Product pipelines provide least cost access from Alabama to regions 2, 4, 17, 18, 28 and 30. Pipeline transport is less expensive than marine tanker shipment to the Atlantic coastal regions.

The Fort Union region provides least cost access via pipeline to the mid-Atlantic interior, and within the Fort Union supply region, while the Powder River supply region is least expensive for much of the western U.S. (regions 11, 13 and 14). Details of the cost figures and modes used to establish all the least cost routes are shown in Exhibit 4.

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Appendix B: Abbreviations

ATSFRR	Atcheson, Topeka and Sante Fe railroad
CRRR	Consolidated Rail Corporation (CONRAIL)
CSXTRP	CSX Transportation, Inc.
D&RGWRR	Denver & Rio Grande Western railroad
MPRR	Missouri Pacific railroad
MSRCRR	Mid-South Rail Corporation
NSRR	Norfolk-Southern railroad
SooLine	Soo Line railroad
UPRR	Union Pacific railroad
GLV	Great Lakes Vessel
Ship	Marine vessel, tanker or collier
dwt	dead weight tons

ABGE	identifies the rate equation
BBGE	used for barge transport
CBGE	by river reach, e.g.
DBGE	A, B, C, D, or E.
EBGE	

Appendix C: Derivation of the Rate Equations

Rate equations for transportation prices over the routes between supply and demand centroids have been calculated using a three step process:

- Equations were developed using published sources that supplied engineering cost data from which cost relationships were inferred,
- Cost equations were developed from these equations so that the final form of the equations used was in one of two forms:
 - 1) $ax+b$, where b is a constant, or fixed cost factor, and where a is a variable cost factor, and x represents mileage.
 - 2) ax , where a is technical cost factor and x represents mileage
- The third step was to calibrate the rate equations against recent (1988) data reflecting actual charges for specific routes with known mileage.

The result of these steps is a set of equations that determine rates in 1988 dollars using technical factors and known mileage. While many of the routes used in this study are not commonly used for shipping fuel products at present, they have been priced by linear extrapolation from prices known to have been charged for similar service over comparable mileage during 1988, or in the case of some railroad routes, by using rates published by railroads for planned shipments during 1988. Thus all the prices provided in the attached appendix are as realistic, given the hypothetical nature of these routes, as engineering models of cost formation and recent practice in actual fuel transportation can make them.

The unit transportation cost of a fuel will vary by the mode of transport used and the route, i.e. distance. The following is an analysis for various modes of moving a liquid or solid material within the United States.

The modes analyzed include:

- Great Lakes Vessel,
- Fresh Water Barge,
- Rail,

- Pipeline (product and crude),
- Truck, and
- Ocean Shipping.

C-1. Fresh Water Barge Transportation

Operating charges and size of the tow, i.e. its capacity, will vary by type of waterway. The waterways in the U.S. can be divided into the following types in order of increasing capacity of maximum tow, and therefore decreasing cost per ton-mile.

Type	Waterways
A	Allegheny, Green and Monongahela Rivers
B	Gulf Intracoastal Waterway, Kanawha River, Red River, Arkansas River, Missouri River.
C	Black Warrior and Tombigbee Rivers (Tenn-Tom Waterway)
D	Illinois Waterway and the Cumberland, Ohio, Tennessee and Upper Mississippi Rivers
E	Lower Mississippi

Exhibit 8 gives estimates of various parameters for five types of U.S. waterways. The "average speed" is an average of full and empty journeys, and takes into account lock and other navigational delays. "Hours in port" is the total time spent loading, unloading and maneuvering. For the purposes of this study, it is estimated that towboats and barges operate 24 hours per day, 350 days per year, with the remaining days spent in maintenance. While many barges may work a shorter year, the competition from fully utilized equipment is assumed to set prices.

Exhibit 8: Estimates of Waterway Parameters

	Waterway Type				
	A	B	C	D	E
Towboat Size (Hp)	1800	1800	1800	5600	8400
Barges Per Tow	4	4	6	15	30
Average Speed (Mph)	4	5	6	6	7
Hours In Port (Hrs)	6	6	8	19	38

	Towboats			Barges
Towboat Size (Hp)	1800	5600	8400	N/A
Barge Capacity (Tons)	N/A	N/A	N/A	1500
Capital Cost (1988 x 10 ⁶ \$)	1.7	4.0	6.0	0.25
Crew Cost (1988 x 10 ³ \$)	369	510	610	0
Fuel Used (Gal/Hr)	66	205	308	0
Fuel Cost (\$/Gal)	0.59	0.59	0.59	0
Other Operating Cost (1988 x 10 ³ \$/Yr)	354	482	567	7

The barged components of the routes used in this study were broken down into segments according to the type of barge waterway utilized. Thus a shipment from New Orleans to East Peoria, IL would have the following components:

New Orleans to Cairo, IL, 786 miles on an "E" waterway, the lower Mississippi;

Cairo, IL to Grafton IL, 218 miles on a "D" waterway, the upper Mississippi;

Grafton, IL to East Peoria, IL, 162 miles on a "D" waterway, the Illinois River.

This trip is, therefore, priced at two rates:

EBGE - 786 miles

DBGE - 380 miles (218+162=380)

Note that no transloading charges are required in moving from one type of barge waterway to another...the tow size may be revised, but the fuel stays in the same barges. Informed readers may question why no rate differentiation is provided between upstream and downstream trips on rivers. It is true that favorable upstream rates are often available, particularly on the lower Mississippi where the volume of upstream traffic in solid bulk cargoes is often much less than the downstream flow of coal and grain. Fuel costs are much less for barge tows moving downstream, again particularly on the lower Mississippi where the mainstream current may exceed 20 knots. It is also true that much of the downstream traffic is dedicated for multiple trips, and may not be contractually permitted to carry upstream cargoes. The market for reduced cost upstream traffic is small and subject to short term variability. Variations in costs due to such factors are viewed as within the range of normal negotiation for services, and no attempt is made to represent them here.

One other aspect of the barge shipments simulated in the attached database requires comment. We have made rather heavy use of a lightly utilized river. The Missouri river is subject to restrictions on barge navigation due to winter freezing and summer-fall low water events. For the most part, railroads moving traffic eastward parallel to the trans-Missouri state course of this river price their services to be competitive with river barge service if the shipper appears to be knowledgeable about the presence of this alternative, and actual costs for rail and barge service, particularly between Kansas City, KS and St. Louis, MO tend to be closely competitive. We encountered numerous cases in which it was economical to ship eastward to

the Missouri by pipeline, but not beyond it. Given the choice of using 1.) a combination of rail to St. Louis, and then barge beyond St. Louis or 2.) transloading to barges at Sioux City, Omaha or Kansas City for shipment to points east, north or south of St. Louis, we always chose the second alternative to avoid additional transloading charges in St. Louis. Such charges, on the order of \$1.50-\$2.00 per ton, roughly equal the maximum difference between rail and barge transport on such routes, and we felt our responsibility was to show the minimum cost method, that is, by barge. Readers should note that shippers who must avoid unpredictable delays due to water conditions on the lower Missouri will pay a cost premium of \$1.50 to \$2.00 per ton to ship by rail to St. Louis.

Based on the most current data the following estimates for unit cost can be derived in 1988 \$ per short ton shipped for:

Solids

- $0.146 + 0.015 \times D_m$ for type A waterways
- $0.146 + 0.012 \times D_m$ for type B waterways
- $0.141 + 0.007 \times D_m$ for type C waterways
- $0.248 + 0.006 \times D_m$ for type D waterways
- $0.378 + 0.004 \times D_m$ for type E waterways

Liquids (Double hulled barges)

- $0.154 + 0.016 \times D_m$ for type A waterways
- $0.154 + 0.013 \times D_m$ for type B waterways
- $0.148 + 0.008 \times D_m$ for type C waterways
- $0.319 + 0.007 \times D_m$ for type D waterways
- $0.403 + 0.004 \times D_m$ for type E waterways

C-2. Great Lakes Vessel Transport

Shipment of bulk solids (and liquids) on the Great Lakes involves use of vessels specially designed to transit the locks at Sault Ste. Marie and on the Welland Canal, and if moving east of Lake Ontario, the Saint Lawrence Seaway. Vessels of 20,000 dead weight tons are

common. Costs for time charters of such vessels may currently be estimated by the equation:

$$1.10 + .0035 \times D_m$$

Thus, the nearly two thousand mile voyage from Superior, WI to Sept Isles, P.Q., on the lower St. Lawrence River (a major transloading terminal for Great Lakes vessels and ocean shipping) can be made for about \$8.00 per short ton. Three demand centroids have been placed on the Great Lakes, and wherever possible, the inexpensive Great Lakes vessel (GLV) has been utilized. This mode of transport can be used from the Burlington Northern Terminal at Superior, WI, and from Sept Isles, P.Q., where cargoes from Vancouver, Portland, Port Arthur, New Orleans and Mobile could be transloaded. Readers will note that solid fuel could be shipped to Lorain, OH, (on the shore of Lake Erie) from Longview, TX for about \$19.00/ton-using ocean and Great Lakes vessels, assuming shipment in 30,000 dwt vessels¹. Between Gulf Coast marine terminals and Sept Isles vessels of two to three times this size may be used, reducing costs by a further \$2.00-\$3.00 per short ton. This serves to emphasize once again that in bulk cargo transport, the shortest route between two points is seldom the least expensive.

C-3. Rail Transportation. Liquid Fuels

Rail transportation costs for liquid products, such as petroleum, can be divided between costs of the tank car or cars used and costs of the rail tariff. A typical rail tank for unit car movements cost about \$90,000 for a 551 barrel tank car. The locomotives are 3000 horsepower (2.2 MW) diesel electric with an estimated 20 year life. An approximate 10% reserve of locomotives and cars are needed to allow for their time out of service for maintenance. The total unit cost can be estimated by the summation of the capital and operating costs. The total cost is given by:

$$\text{Total Cost} = \text{Maintenance Cost} + \text{Capital Cost} + \text{Marginal Track Maintenance Cost} + \text{Rail Replacement Cost} + \text{Rail Operating Cost}$$

¹Ocean vessels in the 20,000-30,000 dwt class often have too broad a beam to use the locks at Sault Ste. Marie, and thus cannot reach lake ports on Lake Superior.

Combining these factors and using current values, the unit train cost is given by the following estimate in 1988 \$ per short ton:

$$4.03 + 0.031 \times D_m$$

where D_m = distance in statute miles

C-4. Rail Transportation, Solid Fuels

A similar process was used to derive unit train rates for coal, which were assumed to be identical to rates for new solid fuel forms. In comparing the derived equations with actual rates for 75 unit train routes operating or planned during 1988, it was found that a better fit could be obtained by constructing two rates, one for unit trains west of the Mississippi and one for eastern rates. Many transportation models of coal movement, such as the Energy Information Administration's National Coal Model have come to the conclusion that coal unit train rates are substantially higher east of the Mississippi, and have represented this increase on trans-Mississippi River routes by dividing the route into separately priced eastern and western components, or by adding a flat charge for crossing the river. This study adopts the first approach, with the following results:

Eastern unit train rate (1988 data)²:

$$\text{\$5.16/short ton} + (0.016 \times \text{mileage})$$

Western unit train rate (1988 data)²:

$$\text{\$3.98/short ton} + (0.011 \times \text{mileage})$$

Unit train rates are usually subject to negotiation and vary depending on the degree to which the shipper is prepared to share the fixed costs of the shipment by, for example, buying the rolling stock and motive power for the required train or trains. The rates used here assume no shipper participation in fixed costs.

²These rates were calibrated against those obtained from class I railroads for U.S. DOE's Coal Logistics System during the summer of 1988.

C-5. Pipeline Transportation

The cost of a pipeline is a function of the: (1) daily throughput, (2) type of petroleum (either product or crude) for which the pipeline is intended, (3) average elevation change in feet, (4) distance between the origin and destination, and (5) the region within which the pipeline will be located or traversed, such as offshore, onshore, mountainous or arctic. Taking these factors into account with current cost of building and operating petroleum pipelines results in the following unit cost equation in 1988 mils \$ per barrel:

$$K \times D_m$$

where D_m = distance liquid transported, and

K = Constant given by Exhibit 9 for various size lines and terrains.

C-6. Truck Transportation

The economics of tank truck transportation depend on a large number of factors. In computing costs, time for a complete round trip is used, including loading, unloading and waiting time. Based on the current operating costs for truck transport the following unit cost estimate can be derived for 1988 \$ per short ton for liquid fuel forms:

$$0.0673 \times D_m$$

Rates for truck carriage of abrasive solids such as stone, coal, or char are higher than those for tanker trucks since trucks must be depreciated in 5 years. Rates for coal truck transportation -- usually carried out in 25 ton trucks with hopper car type body -- were checked against available data for 1988 and produced the following equation:

$$\$3.75/\text{short ton} + (\$0.0375 \times D_m)$$

Exhibit 9: Pipeline Cost Relationships

Dia (inches)	Pipeline Cost Constant (K) (1988 Mils or 10 ³ \$/Bbl-Mile)						
	Capacity ¹ (10 ³ Bbl/Day)		Crude Oil			Product	
	Crude	Product	Flat	Mountainous	Arctic	Flat	Mountainous
6	9	16.8	7.73	10.69	13.64	7.81	11.23
8	17	35.0	5.10	7.17	9.26	5.77	8.42
10	27	64.1	3.79	5.39	6.98	4.85	7.16
12	38	89.0	3.03	4.32	5.63	3.74	5.53
14	50		2.52	3.63	4.72		
16	70	200.0	2.10	2.92	3.83	3.18	4.85
18	93		1.69	2.44	3.20		
20	121	355.9	1.42	2.07	2.71	2.84	4.28
22	158		1.21	1.76	2.33		
24	197	576.3	1.05	1.55	2.03	2.64	4.00
26	238		.94	1.36	1.80		
28	285		.84	1.22	1.62		
30	340	935.1	.74	1.11	1.45	2.10	3.15
32	408		.68	1.01	1.33		
34	474		.62	.94	1.21		
36	548	1589.8	.57	.85	1.11	2.16	3.23
38	622		.53	.79	1.02		
40	696	1996.2	.48	.72	.94	1.93	2.90
42	781	2219.1	.44	.65	.88	1.84	2.75
44	873		.43	.64	.85		
46	972		.40	.60	.79		
48	1232	3160.2	.40	.60	.79	1.79	2.67

- 1) Capacity is defined as the maximum throughput for which a given pipeline size is more cost effective than the next larger size.
- 2) "Capital Requirements for the transportation of energy materials based on PIES Scenario Estimates", U.S. Dept. of Energy, DOE/EIA -- 0102/47, January 1979, pg. 43.
- 3) Pump stations 50 mile spacing; 1440 psig maximum working pressure or 72% of minimum yield strength of X-60 pipe product mix: 2/3 gasoline + 1/3 heating oil -- Miller equation.
- 4) "Crude Supply Alternatives For The Northern Tier States" Volume II, Technical Report, Bonner; Moore Associates, Inc., 25 July 1976, pg. B.4.

Coal haulage can thus be achieved at the following prices:

20 miles	\$4.50/short ton
40 miles	\$5.25
80 miles	\$6.75
100 miles	\$7.50

C-7. Transloading Charges

Many of the routes employed require the utilization of one or more modes of transportation.

Where this occurs, transloading charges have been added as follows³.

Ship to barge, ship to Great Lakes vessel, (solid fuels)	\$1.00/ton
Ship to barge, ship to Great Lakes vessel, (liquid fuels)	\$0.50/ton
Rail to barge transfer (solid fuels), no storage assumed	\$1.00/ton
Rail to barge transfer (liquid fuels), no storage assumed	\$0.50/ton
Truck to rail, truck to barge (solid fuels), no storage assumed	\$0.75/ton
Truck to rail, truck to barge (liquid fuels), no storage assumed	\$0.35/ton
Pipeline to rail or barge, storage assumed	\$2.00/ton

Transloading from any mode to ocean vessel produces port-specific costs. Pacific coast ports are generally more expensive than Atlantic and Gulf Coast ports. Rates for loading liquids are, like those for solids, functions of the time required. We have assumed that a 30,000 dwt tanker can be loaded with liquid fuels in half the time required for solids.

C-8. Transport of Fuels by Ocean Vessel

The relatively low cost per ton-mile of ocean shipping for bulk cargoes recommends its use wherever possible. Three of the nine supply region centroids used in this work are within 250 miles of marine bulk cargo terminals:

Centralia, WA: Roberts Bank (solids), Vancouver, B.C., Canada (solids)
Portland, OR (liquids)

³These charges are those contained in U.S. DOE's Coal Logistics Systems, which were obtained during the summer of 1988.

Longview, TX: Port Arthur, TX (solids & liquids)

York, AL: Mobile, AL (solids & liquids)

New Orleans, LA (solids & liquids)

Likewise, a large number of demand region centroids are at or close to marine receiving terminals. Wherever possible, their use has been emphasized in the attached database.

In order to estimate spot charter rates for bulk cargo rates, a simplified marine rate equation was adopted from US DOE/FE's U.S.-Italian Coal Logistics System. The equation used in that source was:

$$y = ((.1983((x_1^{.4963})(x_2^{.9592})(x_3^{-.6324})))-.03)$$

Where y = the marine rate, in \$/per long ton of 2240lbs.

x_1 = \$/long ton marine diesel fuel price.

x_2 = charter time submodel (see below).

x_3 = cargo size in thousand long tons.

and the charter time submodel, x_2 is defined as

$$x_2 = (((\text{nautical miles} * 2.034)/(\text{knots} * 24)) + \text{loading, unloading \& maneuver time in days})$$

This equation was further simplified by substituting constants for variables as follows:

- a) The price of marine diesel fuel was assumed to be \$170/long ton.
- b) The vessel's average speed was assumed to be 15 knots/hour.
- c) The vessel used was assumed to be a 30,000 dead weight ton "handy-size" ship designed for shallow draft ports. Such vessels typically exhibit fully loaded draught of about 22 feet with a maximum beam of under 85 feet and a paying cargo capacity of 25,000 to 28,000 short tons.

- d) The loading, unloading and maneuver time allowance for the routes under consideration was assumed to be 7.0 days for solid bulk cargo vessels and 2.5 days for tankers.
- e) The results of this simplified equation were multiplied by 0.8929 to yield results in \$/short ton rather than \$/long ton.

With these simplifications, the resulting equations were derived:
for solid bulk cargoes:

$$y_1 = [(.2637((\text{nautical miles}/176.99)+7)^{.9592} - .03]$$

for liquid cargoes:

$$y_2 = [(.2637((\text{nautical miles}/176.99)+2.5)^{.9592} - .03]$$

Thus, the 1210 nautical mile voyage from the Burnside, LA terminal to Port Wentworth, GA would cost:⁴

$$y_1, \text{ for solid cargoes} = [(.2637)((1210/176.99)+7)^{.9592} - .03] = \$3.25$$

$$y_2 \text{ for liquid cargoes} = [(.2637)((1210/176.99)+2.5)^{.9592} - .03] = \$2.22$$

It should be noted that all the above transportation rates reflect 1988 costs in 1988 dollars. It is inappropriate to assume that these rates can be inflated to 1989 or future dates by use of standard indexes such as the GNP deflator. In general, fixed cost terms may be inflated by using estimates of the cost of capital, while variable costs may increase or decrease with the cost of diesel fuel oil, the primary fuel for railroads, trucks, towboats and Great Lakes and marine vessels (an extremely useful indicator of general operating costs in basic industries).

⁴Office of Fossil Energy, Documentation and User's Guide, the Coal Logistics System. Washington, D.C.: U.S. Department of Energy, October, 1988.

Exhibit 10.1: Transportation Costs for Supply Region 1 - Northwest (Centralla, WA)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
I. Demand Regions Not on Navigable Waterways									
1	2,672	Rail/Ship/ Rail	28.12	Rail/Ship/ Rail	30.77	Pipe/Ship/ Rail	21.02	Rail/Ship/ Rail	30.77
2	14,475	Rail/Ship/ Rail	27.46	Rail/Ship/ Rail	29.00	Pipe/Ship/ Rail	19.74	Rail/Ship/ Rail	29.00
3	50,150	Rail	41.02	Rail	88.79	Rail	88.79	Rail	88.79
4	58,359	Rail/Ship/ Rail	28.04	Rail/Ship/ Rail	33.27	Pipe/Ship/ Rail	23.51	Rail/Ship/ Rail	33.27
5	12,369	Rail	34.26	Rail	81.13	Rail	81.13	Rail	81.13
6	31,893	Rail	34.57	Rail	89.03	Rail	89.03	Rail	89.03
7	2,379	Rail	30.04	Rail	76.45	Rail	76.45	Rail	76.45
8	20,039	Rail	29.31	Rail	74.40	Rail	74.40	Rail	74.40
9	11,473	Rail	22.83	Rail	64.36	Rail	64.36	Rail	64.36
10	17,837	Rail	24.22	Rail	60.26	Rail	60.26	Rail	60.26
11	5,920	Rail	21.08	Rail	51.55	Rail	51.55	Rail	51.55
12	4,550	Rail	14.73	Rail	33.91	Rail	33.91	Rail	33.91
13	4,989	Rail	15.43	Rail	35.84	Rail	35.84	Rail	35.84
14	2,609	Rail	15.64	Rail	36.43	Rail	36.43	Rail	36.43
15	5,709	Rail	6.80	Rail	11.87	Rail	11.87	Rail	11.87
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/Ship	19.59	Rail/Ship	21.65	Pipe/Ship	11.89	Rail/Ship	21.65
17	9,369	Rail/Ship	18.51	Rail/Ship	20.39	Pipe/Ship	10.83	Rail/Ship	20.39

Exhibit 10.1: Transportation Costs for Supply Region 1 - Northwest (Centralla, WA)
(continued)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Ccoal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
18	17,325	Rail/Ship/Barge	21.17	Rail/Ship/Barge	23.44	Pipe/Ship/Barge	13.68	Rail/Ship/Barge	23.44
19	9,951	Rail/Ship/Barge	23.01	Rail/Ship/Barge	25.20	Pipe/Ship/Barge	15.34	Rail/Ship/Barge	25.20
20	10,605	Rail/Ship/Barge	23.15	Rail/Ship/Barge	25.24	Pipe/Ship/Barge	15.38	Rail/Ship/Barge	25.24
21	19,143	Rail/Ship/Barge	27.89	Rail/Ship/Barge	29.98	Pipe/Ship/Barge	21.81	Rail/Ship/Barge	29.98
22	8,967	Rail/Ship/Barge	25.68	Rail/Ship/Barge	28.22	Pipe/Ship/Barge	18.36	Rail/Ship/Barge	28.22
23	6098	Rail/Ship/Barge	28.41	Rail/Ship/Barge	30.82	Pipe/Ship/Barge	20.96	Rail/Ship/Barge	30.82
24	2,167	Rail/Ship/Barge	26.21	Rail/Ship/Barge	28.25	Pipe/Ship/Barge	18.39	Rail/GLV	28.25
25	3,946	Rail/GLV	28.93	Rail/GLV	66.60	Pipe/Ship/GLV	19.43	Rail/GLV	66.60
26	16,081	Rail/GLV	29.42	Rail/GLV	67.09	Pipe/Ship/GLV	20.74	Rail/GLV	67.09
27	43,608	Rail/Ship/Barge	24.91	Rail/Ship/Barge	27.32	Pipe/Ship/Barge	17.46	Rail/Ship/Barge	27.32
28	23,834	Rail/GLV	29.61	Rail/GLV	67.28	Pipe/Ship/GLV	18.75	Rail/GLV	67.28
29	50,403	Rail/Ship/Barge	28.32	Rail/Ship/Barge	31.31	Pipe/Ship/Barge	21.45	Rail/Ship/Barge	31.31
30	12,891	Rail/Ship	18.82	Rail/Ship	20.88	Pipe/Ship	11.12	Rail/Ship	20.88

Exhibit 10.2: Transportation Costs for Supply Region 2 - Powder River (Gillette, WY)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
		I. Demand Regions Not on Navigable Waterways							
1	2,672	Rail	30.45	Pipe/Rail	30.54	Rail	70.52	Rail	70.52
2	14,475	Rail	29.33	Pipe/Rail	33.05	Rail	67.42	Rail	67.42
3	50,150	Rail	24.30	Pipe	11.03	Rail	53.45	Rail	53.45
4	58,359	Rail	27.10	Pipe/Barge/Ship/Rail	35.10	Rail	63.21	Rail	63.21
5	12,369	Rail	20.32	Pipe	11.87	Rail	42.38	Rail	42.38
6	31,893	Rail	20.37	Pipe	18.74	Rail	49.57	Rail	49.57
7	2,379	Rail	15.84	Pipe	29.21	Rail	36.98	Rail	36.98
8	20,039	Rail	15.55	Pipe	14.35	Rail	36.46	Rail	36.46
9	11,473	Rail	10.29	Rail	25.54	Rail	25.54	Rail	25.54
10	17,837	Rail	11.42	Pipe/Rail	19.82	Rail	24.71	Rail	24.71
11	5,920	Rail	19.97	Pipe/Truck	19.40	Rail	48.45	Rail	48.45
12	4,550	Rail	13.06	Pipe	9.98	Rail	29.26	Rail	29.26
13	4,989	Rail	7.68	Pipe	9.20	Rail	11.53	Rail	11.53
14	2,609	Rail	23.49	Pipe	16.87	Rail	66.19	Rail	66.19
15	5,709	Rail	15.68	Rail	44.49	Truck/Pipe	38.51	Rail	44.49

Exhibit 10.2: Transportation Costs for Supply Region 2 - Powder River (Gillette, WY)
(continued)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/GLV/Ship	31.29	Pipe/Barge/Ship	23.72	Rail/GLV/Ship	55.69	Rail/GLV/Ship	55.69
17	9,369	Rail/Barge	26.80	Pipe/Barge	19.61	Rail/Barge	44.37	Rail/Barge	44.37
18	17,325	Rail/Barge	25.37	Pipe/Barge	19.81	Rail/Barge	43.20	Rail/Barge	43.20
19	9,951	Rail/Barge	26.38	Pipe/Barge	19.28	Rail/Barge	44.04	Rail/Barge	44.04
20	10,605	Rail/Barge	23.28	Pipe/Barge	16.06	Rail/Barge	40.82	Rail/Barge	40.82
21	19,143	Rail/Barge	17.62	Pipe	7.41	Rail/Barge	34.54	Rail/Barge	34.54
22	8,967	Rail/Barge	23.21	Pipe/Barge	15.99	Rail/Barge	40.74	Rail/Barge	40.74
23	6,098	Rail/Barge	18.02	Pipe/Barge	18.58	Rail/Barge	39.98	Rail/Barge	39.88
24	2,167	Rail/Barge	20.22	Pipe/Barge	16.01	Truck/Pipe/Barge	46.87	Rail/Barge	42.55
25	3,946	Rail/GLV	21.58	Pipe/Truck	21.04	Rail/GLV	45.89	Rail/GLV	45.89
26	16,081	Rail/GLV	22.07	Pipe/Truck	20.18	Rail/GLV	43.38	Rail/GLV	43.38
27	43,608	Rail/Barge	24.80	Pipe/Barge	17.83	Rail/Barge	42.59	Rail/Barge	42.59
28	23,834	Rail/GLV	22.26	Pipe/Truck	19.52	Rail/GLV	46.57	Rail/GLV	46.57
29	50,403	Rail/Barge	28.21	Pipe/Barge	21.81	Rail/Barge	46.57	Rail/Barge	46.57
30	12,891	Rail/GLV/Ship	31.87	Pipe/Barge/Ship	22.71	Pipe/Barge/Ship	53.57	Rail/GLV/Ship	56.27

Exhibit 10.3: Transportation Costs for Supply Region 3 - Fort Union (Bismarck, ND)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
L Demand Regions Not on Navigable Waterways									
1	2,672	Rail	25.09	Pipe/Rail	33.77	Pipe/GLV/ Ship/Rail	37.42	Rail/GLV/ Ship/Rail	42.58
2	14,475	Rail	26.31	Pipe/Rail	36.28	Pipe/GLV/ Ship/Rail	40.25	Rail/GLV/ Ship/Rail	45.41
3	50,150	Rail	20.27	Pipe	25.27	Rail	42.25	Rail	42.25
4	58,359	Rail	28.20	Rail/GLV/ Ship/Rail	47.70	Pipe/Barge/ Ship/Rail	40.16	Rail/GLV/ Ship/Rail	47.70
5	12,369	Rail	25.72	Rail/Pipe	28.33	Pipe	42.51	Rail	59.39
6	31,893	Rail	24.66	Rail/Pipe	33.05	Rail	62.31	Rail	62.31
7	2,379	Rail	20.49	Rail/Pipe	34.88	Rail	49.91	Rail	49.91
8	20,039	Rail	15.37	Rail/Pipe	28.65	Rail	35.68	Rail	35.68
9	11,473	Rail	16.31	Rail	38.29	Rail	38.29	Rail	38.29
10	17,837	Rail	8.84	Rail	19.53	Rail	19.53	Rail	19.53
11	5,920	Rail	28.03	Rail/Pipe/ Truck	35.54	Rail	70.87	Rail	70.87
12	4,550	Rail	16.02	Rail/Pipe	25.54	Rail	37.48	Rail	37.48
13	4,989	Rail	8.96	Rail	19.84	Rail	19.84	Rail	19.84
14	2,609	Rail	24.66	Rail/Pipe	31.30	Rail	61.50	Rail	61.50
15	5,709	Rail	18.08	Rail	43.21	Rail	43.21	Rail/GLV/ Ship	43.21

Exhibit 10.3: Transportation Costs for Supply Region 3 - Fort Union (Bismarck, ND)
(continued)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/GLV/Ship	23.85	Rail/GLV/Ship	34.73	Pipe/GLV/Ship	29.57	Rail/GLV/Ship	34.73
17	9,369	Rail/Barge	19.04	Rail/Barge	29.06	Pipe/Barge	24.67	Rail/Barge	29.06
18	17,325	Rail/Barge	21.19	Rail/Barge	31.43	Pipe/Barge	24.87	Rail/Barge	31.43
19	9,951	Rail/Barge	17.48	Rail/Barge	28.73	Pipe/Barge	24.34	Rail/Barge	28.73
20	10,605	Rail/Barge	21.16	Pipe/Barge	30.52	Pipe/Barge	21.12	Rail/Barge	32.55
21	19,143	Rail/Barge	15.50	Rail/Barge	26.27	Pipe/Barge	24.48	Rail/Barge	26.27
22	8,967	Rail/Barge	31.03	Pipe/Barge	30.13	Pipe/Barge	20.73	Rail/Barge	44.06
23	6,098	Rail/Barge	11.01	Rail/Barge	20.24	Pipe/Barge	16.99	Rail/Barge	20.24
24	2,167	Rail/Barge	13.21	Rail/Barge	22.81	Pipe/Barge	19.56	Rail/Barge	22.81
25	3,946	Rail/GLV	14.76	Pipe/Truck	26.20	Pipe/GLV	22.58	Rail/GLV	26.67
26	16,081	Rail/GLV	15.25	Pipe/Truck	24.84	Pipe/GLV	23.07	Rail/GLV	27.16
27	43,608	Rail/Barge	21.91	Pipe/Barge	32.28	Pipe/Barge	22.88	Rail/Barge	33.06
28	23,834	Rail/GLV	15.44	Pipe/Truck	26.13	Pipe/GLV	23.26	Rail/GLV	27.35
29	50,403	Rail/Barge	26.09	Pipe/Barge	36.26	Pipe/Barge	26.86	Rail/Barge	36.30
30	12,891	Rail/GLV/Ship	24.43	Rail/GLV/Ship	35.31	Pipe/Barge/Ship	27.77	Rail/GLV/Ship	35.31

Exhibit 10.4: Transportation Costs for Supply Region 4 - South Wyoming (Rock Springs, WY)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
I. Demand Regions Not on Navigable Waterways									
1	2,672	Rail	32.54	Pipe/Rail	32.27	Pipe/GLV/ Ship/Rail	57.31	Rail/GLV/ Ship/Rail	65.52
2	14,475	Rail	31.57	Pipe	34.78	Pipe/GLV/ Ship/Rail	49.80	Rail/GLV/ Ship/Rail	56.26
3	50,150	Rail	25.15	Pipe	12.40	Rail	55.83	Rail	55.83
4	58,359	Rail	30.33	Pipe/Barge/ Ship/Rail	40.55	Pipe/Barge/ Ship/Rail	57.44	Pipe/Barge/ Ship/Rail	64.02
5	12,369	Rail	22.02	Pipe	13.79	Pipe	46.96	Rail	47.12
6	31,893	Rail	20.75	Pipe	21.13	Pipe	36.82	Rail	50.62
7	2,379	Rail	16.22	Pipe	32.08	Rail	38.04	Rail	38.04
8	20,039	Rail	17.14	Pipe	17.22	Rail	40.61	Rail	40.61
9	11,473	Rail	10.67	Rail	22.63	Rail	22.63	Rail	22.63
10	17,837	Rail	14.09	Pipe/Truck	35.85	Rail	32.12	Rail	32.12
11	5,920	Rail	19.91	Pipe/Rail	21.44	Rail	48.30	Rail	48.30
12	4,550	Rail	6.51	Pipe/Truck	20.13	Rail	11.07	Rail	11.07
13	4,989	Rail	12.44	Pipe	3.23	Rail	27.53	Rail	27.53
14	2,609	Rail	15.16	Pipe	9.98	Rail	35.09	Rail	35.09
15	5,709	Rail	15.15	Pipe	18.13	Rail	29.51	Rail	29.51

Exhibit 10.4: Transportation Costs for Supply Region 4 - South Wyoming (Rock Springs, WY)
(continued)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/GLV/ Ship	31.99	Pipe/Barge/ Ship	30.86	Pipe/GLV/ Ship	49.46	Rail/GLV/ Ship	57.67
17	9,369	Rail/Barge	26.43	Pipe/Barge	26.75	Pipe/Barge	41.95	Rail/Barge	48.41
18	17,325	Rail/Barge	25.00	Pipe/Barge	26.95	Pipe/Barge	42.15	Rail/Barge	47.24
19	9,951	Rail/Barge	26.01	Pipe/Barge	26.42	Pipe/Barge	41.62	Rail/Barge	48.08
20	10,605	Rail/Barge	22.91	Pipe/Barge	23.20	Pipe/Barge	38.40	Rail/Barge	44.86
21	19,143	Rail	15.51	Pipe	14.55	Pipe/Barge	32.12	Rail	36.52
22	8,967	Rail/Barge	32.78	Pipe/Barge	23.12	Pipe/Barge	38.32	Rail/Barge	56.37
23	6,098	Rail/Barge	25.07	Pipe/Barge	25.72	Pipe/Barge	40.92	Rail/Barge	47.38
24	2,167	Rail/Barge	22.87	Pipe/Barge	23.15	Pipe/Barge	38.35	Rail/Barge	44.81
25	3,946	Rail/GLV	22.91	Pipe/Truck	20.27	Pipe/GLV	41.52	Rail/GLV	49.64
26	16,081	Rail/GLV	23.40	Pipe/Truck	19.41	Pipe/GLV	42.01	Rail/GLV	50.13
27	43,608	Rail/Barge	24.43	Pipe/Barge	24.97	Pipe/Barge	40.17	Rail/Barge	46.63
28	23,834	Rail/GLV	23.59	Pipe/Truck	21.95	Pipe/GLV	42.20	Rail/GLV	50.32
29	50,403	Rail/Barge	27.84	Pipe/Barge	28.95	Pipe/Barge	44.15	Rail/Barge	50.61
30	12,891	Rail/Barge/ Ship	30.68	Pipe/Barge/ Ship	28.16	Pipe/Barge/ Ship	45.05	Rail/Barge/ Ship	51.63

Exhibit 10.5: Transportation Costs for Supply Region 5 - Denver Basin (Denver, CO)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
I. Demand Regions Not on Navigable Waterways									
1	2,672	Rail	29.73	Pipe/Rail	30.63	Pipe/GLV/ Ship/Rail	51.74	Rail/GLV/ Ship/Rail	58.11
2	14,475	Rail	28.76	Pipe/Rail	33.14	Pipe/GLV/ Ship/Rail	54.47	Rail/GLV/ Ship/Rail	60.94
3	50,150	Rail	22.34	Pipe	11.11	Rail	51.99	Rail	51.99
4	58,359	Rail	24.34	Pipe/Barge/ Ship/Rail	38.89	Pipe/Barge/ Ship/Rail	44.20	Rail	55.55
5	12,369	Rail	19.21	Pipe	11.98	Rail	39.31	Rail	39.31
6	31,893	Rail	16.26	Pipe	18.88	Rail	38.16	Rail	38.16
7	2,379	Rail	11.85	Rail	25.89	Rail	25.89	Rail	25.89
8	20,039	Rail	12.46	Pipe	14.52	Rail	27.59	Rail	27.59
9	11,473	Rail	5.99	Rail	9.61	Pipe	7.44	Rail	9.61
10	17,837	Rail	12.14	Rail	26.69	Rail	26.69	Rail	26.69
11	5,920	Rail	15.71	Pipe/Truck	18.94	Rail	36.61	Rail	36.61
12	4,550	Rail	10.53	Pipe	10.18	Rail	21.73	Rail	21.73
13	4,989	Rail	10.21	Pipe	9.40	Rail	21.33	Rail	21.33
14	2,609	Rail	19.00	Pipe	16.95	Rail	45.76	Rail	45.76
15	5,709	Rail	17.59	Rail	41.85	Rail	41.85	Rail	41.85

Exhibit 10.5: Transportation Costs for Supply Region 5 - Denver Basin (Denver, CO)
(continued)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/GLV/ Ship	29.36	Pipe/Barge/ Ship	27.51	Pipe/GLV/ Ship	43.89	Rail/GLV/ Ship	50.26
17	9,369	Rail/Barge	22.04	Pipe/Barge	23.40	Pipe/Barge	28.71	Rail/Barge	36.04
18	17,325	Rail/Barge	20.61	Pipe/Barge	23.60	Pipe/Barge	28.91	Rail/Barge	34.87
19	9,951	Rail/Barge	21.62	Pipe/Barge	23.07	Pipe/Barge	25.30	Rail/Barge	35.71
20	10,605	Rail/Barge	18.52	Pipe/Barge	19.85	Pipe/Barge	25.16	Rail/Barge	32.49
21	19,143	Rail	11.12	Pipe	11.20	Pipe/Truck	19.52	Rail	24.15
22	8,967	Rail/Barge	28.39	Pipe/Barge	17.77	Pipe/Barge	25.08	Rail/Barge	44.00
23	6,098	Rail/Barge	20.68	Pipe/Barge	22.37	Pipe/Barge	27.68	Rail/Barge	35.01
24	2,167	Rail/Barge	18.48	Pipe/Barge	19.80	Pipe/Barge	25.11	Rail/Barge	32.44
25	3,946	Rail/GLV	20.27	Pipe/Truck	20.81	Pipe/GLV	37.25	Rail/GLV	42.20
26	16,081	Rail/GLV	20.76	Pipe/Truck	19.96	Pipe/GLV	37.74	Rail/GLV	42.69
27	43,608	Rail/Barge	20.04	Pipe/Barge	21.62	Pipe/Barge	26.93	Rail/Barge	34.26
28	23,834	Rail/GLV	20.95	Pipe/Truck	19.68	Pipe/GLV	37.93	Rail/GLV	42.88
29	50,403	Rail/Barge	23.45	Pipe/Barge	25.60	Pipe/Barge	30.91	Rail/Barge	38.24
30	12,891	Rail/Barge/ Ship	26.29	Pipe/Barge/ Ship	26.50	Pipe/Barge/ Ship	31.81	Rail/Barge/ Ship	39.26

Exhibit 10.6: Transportation Costs for Supply Region 6 - Rocky Mountain (Dotsero, CO)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
I. Demand Regions Not on Navigable Waterways									
1	2,672	Rail	31.85	Truck/Pipe/ Rail	43.62	Rail/GLV/ Ship/Rail	62.99	Rail/GLV/ Ship/Rail	62.99
2	14,475	Rail	30.88	Truck/Pipe/ Rail	46.13	Rail/GLV/ Ship/Rail	50.60	Rail/GLV/ Ship/Rail	51.90
3	50,150	Rail	26.46	Truck/Pipe	23.72	Rail	53.91	Rail	53.91
4	58,359	Rail	26.46	Rail	61.44	Rail	61.44	Rail	61.44
5	12,369	Rail	21.23	Truck/Pipe	25.20	Rail	44.92	Rail	44.92
6	31,893	Rail	17.46	Truck/Pipe	32.62	Rail	41.48	Rail	41.48
7	2,379	Rail	15.04	Rail	29.20	Rail	29.20	Rail	29.20
8	20,039	Rail	15.65	Truck/Pipe	28.76	Rail	34.88	Rail	34.88
9	11,473	Rail	7.18	Rail	12.93	Rail	12.93	Rail	12.93
10	17,837	Rail	14.26	Rail	32.58	Rail	32.58	Rail	32.58
11	5,920	Rail	16.90	Truck/Pipe	33.40	Rail	47.86	Rail	47.86
12	4,550	Rail	10.49	Rail	16.55	Rail	16.55	Rail	16.55
13	4,989	Rail	13.27	Truck/Pipe	21.34	Rail	29.85	Rail	29.85
14	2,609	Rail	17.13	Truck/Pipe	29.15	Rail	40.58	Rail	40.58
15	5,709	Rail	16.65	Rail	39.25	Rail	39.25	Rail	39.25

Exhibit 10.6: Transportation Costs for Supply Region 6 - Rocky Mountain (Dotsero, CO)
(continued)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/GLV/ Ship	31.20	Rail/Pipe/ Barge/Ship	38.72	Rail/GLV/ Ship	55.14	Rail/GLV/ Ship	55.14
17	9,369	Rail/ Barge	23.88	Rail/Pipe/ Barge	32.61	Rail/Pipe/ Barge	39.92	Rail/Barge	41.22
18	17,325	Rail/Barge	22.45	Rail/Pipe/ Barge	34.81	Rail/Barge	40.05	Rail/Barge	40.05
19	9,951	Rail/Barge	23.46	Rail/Pipe/ Barge	34.28	Rail/Pipe/ Barge	39.59	Rail/Barge	40.89
20	10,605	Rail/Barge	30.93	Rail/Pipe/ Barge	31.06	Rail/Pipe/ Barge	36.37	Rail/Barge	49.98
21	19,143	Rail	12.95	Rail/Pipe	22.41	Rail	29.30	Rail	29.30
22	8,967	Rail/Barge	30.21	Rail/Pipe/ Barge	30.98	Rail/Pipe/ Barge	36.29	Rail/Barge	49.14
23	6,098	Rail/Barge	22.52	Rail/Pipe/ Barge	31.58	Rail/Pipe/ Barge	38.89	Rail/Barge	40.19
24	2,167	Rail/Barge	20.32	Rail/Pipe/ Barge	31.01	Rail/Pipe/ Barge	36.32	Rail/Barge	37.62
25	3,946	Rail/GLV	22.11	Rail/Pipe/ Truck	32.02	Rail/GLV	47.38	Rail/GLV	47.38
26	16,081	Rail/GLV	22.60	Rail/Pipe/ Truck	31.17	Rail/GLV	47.87	Rail/GLV	47.87

Exhibit 10.6: Transportation Costs for Supply Region 6 - Rocky Mountain (Dotsero, CO)
(continued)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
27	43,608	Rail/Barge	21.88	Rail/Pipe/Barge	30.83	Rail/Pipe/Barge	38.14	Rail/Barge	39.44
28	23,834	Rail/GLV	22.79	Rail/Pipe/Truck	17.05	Rail/GLV	48.06	Rail/GLV	48.06
29	50,403	Rail/Barge	25.29	Rail/Pipe/Barge	34.81	Rail/Pipe/Barge	42.12	Rail/Barge	43.42
30	12,891	Rail/Barge/Ship	27.87	Rail/Pipe/Barge/Ship	35.71	Rail/Barge/Ship	43.94	Rail/Barge/Ship	43.94

Exhibit 10.7: Transportation Costs for Supply Region 7 - San Juan (Gallup, NM)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Tons
L. Demand Regions Not on Navigable Waterways									
1	2,672	Rail	34.63	Pipe	18.08	Rail/Ship/ Rail	50.77	Rail/Ship/ Rail	50.77
2	14,475	Rail	33.66	Pipe	18.08	Rail/Ship/ Rail	55.02	Rail/Ship/ Rail	55.02
3	50,150	Rail	25.35	Pipe	9.47	Rail	56.36	Rail	56.36
4	58,359	Rail	31.94	Pipe/Ship/ Rail	34.40	Rail/Ship/ Rail	54.50	Rail/Ship/ Rail	54.50
5	12,369	Rail	23.94	Pipe	15.91	Rail	60.39	Rail	60.39
6	31,893	Rail	15.11	Pipe	13.32	Rail	34.97	Rail	34.97
7	2,379	Rail	10.70	Pipe	9.57	Rail	22.69	Rail	22.69
8	20,039	Rail	14.30	Pipe	13.20	Rail	32.71	Rail	32.71
9	11,473	Rail	11.08	Rail	23.75	Rail	23.75	Rail	23.75
10	17,837	Rail	23.23	Pipe/Rail	24.99	Rail	46.41	Rail	46.41
11	5,920	Rail	10.63	Pipe/Truck	12.29	Rail	18.94	Rail	18.94
12	4,550	Rail	16.78	Pipe	36.39	Rail	39.59	Rail	39.59
13	4,989	Rail	18.43	Pipe	35.31	Rail	44.18	Rail	44.18
14	2,609	Rail	12.09	Pipe	5.91	Rail	26.57	Rail	26.57
15	5,709	Rail	22.92	Rail	64.60	Rail	64.60	Rail	64.60

Exhibit 10.7: Transportation Costs for Supply Region 7 - San Juan (Gallup, NM)
(continued)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Tons
II. Demand Regions on Navigable Waterways									
16	18,879	Rail/Ship	21.61	Pipe/Ship	22.83	Rail/Ship	42.92	Rail/Ship	42.92
17	9,369	Rail/Barge	21.70	Pipe/Barge	24.44	Rail/Barge	44.34	Rail/Barge	44.34
18	17,325	Rail/Barge	24.67	Pipe/Barge	27.66	Rail/Barge	47.68	Rail/Barge	47.68
19	9,951	Rail/Barge	19.92	Pipe/Barge	27.47	Rail/Barge	39.84	Rail/Barge	39.84
20	10,605	Rail/Barge	22.87	Pipe/Barge	27.50	Rail/Barge	41.91	Rail/Barge	41.91
21	19,143	Rail	14.81	Rail	34.56	Rail	34.56	Rail	34.56
22	8,967	Rail/Barge	22.07	Pipe/Barge	30.33	Rail/Barge	42.76	Rail/Barge	42.76
23	6,098	Rail/Barge	24.30	Pipe/Barge	33.08	Rail/Barge	45.36	Rail/Barge	45.36
24	2,167	Rail/Barge	22.10	Pipe/Barge	30/51	Rail/Barge	42.79	Rail/Barge	42.79
25	3,946	Rail/Ship/ GLV	29.39	Pipe/Truck	23.56	Rail/Ship/ GLV	50.81	Rail/Ship/ GLV	50.81
26	16,081	Rail/Ship/ GLV	30.70	Pipe/Truck	24.70	Rail/Ship/ GLV	52.12	Rail/Ship/ GLV	52.12
27	43,608	Rail/Barge	22.24	Pipe/Barge	29.58	Rail/Barge	44.68	Rail/Barge	44.68
28	23,834	Rail/Ship/ GLV	28.71	Pipe/Truck	24.29	Rail/Ship/ GLV	50.13	Rail/Ship/ GLV	50.13
29	50,403	Rail/Barge	27.15	Pipe/Barge	53.57	Rail/Barge	48.66	Rail/Barge	48.66
30	12,891	Rail/Ship	20.81	Pipe/Ship	22.01	Rail/Ship	42.11	Rail/Ship	42.11

Exhibit 10.8: Transportation Costs for Supply Region 8 - Texarla (Longview, TX)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
I. Demand Regions Not on Navigable Waterways									
1	2,672	Rail/Ship/ Rail	19.80	Pipe/Ship/ Rail	16.71	Pipe/Ship/ Rail	18.42	Rail/Ship/ Rail	23.55
2	14,475	Rail/Ship/ Rail	22.63	Pipe/Ship/ Rail	19.54	Pipe/Ship/ Rail	21.25	Rail/Ship/ Rail	26.38
3	50,150	Rail	17.59	Pipe	6.62	Rail	34.81	Rail	34.81
4	58,359	Rail	17.17	Pipe/Rail	23.16	Pipe/Ship/ Rail	22.13	Rail/Ship/ Rail	27.28
5	12,369	Rail	18.18	Pipe	10.53	Rail	30.90	Rail	30.90
6	31,993	Rail	6.45	Pipe	3.10	Rail	11.87	Rail	11.87
7	2,379	Rail	7.94	Pipe	5.74	Rail	15.04	Rail	15.04
8	20,039	Rail	8.25	Pipe	5.50	Rail	15.90	Rail	15.90
9	11,473	Rail	12.38	Pipe/Truck	25.05	Rail	27.37	Rail	27.37
10	17,837	Rail	15.00	Pipe/Rail	20.65	Pipe	29.52	Rail	34.66
11	5,920	Rail	19.31	Pipe/Truck	13.39	Rail	46.62	Rail	46.62
12	4,550	Rail	20.09	Pipe	27.47	Rail	48.79	Rail	48.79
13	4,989	Rail	21.74	Pipe	26.24	Rail	61.32	Rail	61.32
14	2,609	Rail	22.77	Pipe	11.16	Rail	56.23	Rail	56.23
15	5,709	Rail	28.01	Rail	70.77	Rail	70.77	Rail	70.77

Exhibit 10.8: Transportation Costs for Supply Region - Texarla (Longview, TX)
(continued)

Demand Regions	1985 Coal Consumption (1000 Short Tons)	Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
		Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	19,879	Rail/Ship	11.95	Pipe/Ship	8.86	Pipe/Ship	10.57	Rail/Ship	15.70
17	9,369	Rail/Barge	12.04	Pipe/Barge	10.47	Pipe/Barge	12.18	Rail/Barge	17.12
18	17,325	Rail/Barge	15.01	Pipe/Barge	13.69	Pipe/Barge	15.40	Rail/Barge	20.46
19	9,951	Rail/Barge	15.04	Pipe/Barge	13.50	Pipe/Barge	15.24	Rail/Barge	20.23
20	10,605	Rail/Barge	15.18	Pipe/Barge	13.53	Pipe/Barge	15.18	Rail/Barge	20.26
21	19,143	Rail/Barge	20.98	Pipe/Barge	19.96	Pipe/Barge	21.67	Rail/Barge	26.69
22	8,967	Rail/Barge	17.71	Pipe/Barge	16.36	Pipe/Barge	18.22	Rail/Barge	23.24
23	6,098	Rail/Barge	19.94	Pipe/Barge	19.11	Pipe/Barge	20.82	Rail/Barge	25.84
24	2,167	Rail/Barge	17.74	Pipe/Barge	16.54	Pipe/Barge	18.25	Rail/Barge	23.27
25	3,946	Rail/Ship/ GLV	19.73	Pipe/Truck	16.81	Rail/Ship/ GLV	23.59	Rail/Ship/ GLV	23.59
26	16,081	Rail/Ship/ GLV	21.04	Pipe/Truck	15.64	Rail/Ship/ GLV	24.90	Rail/Ship/ GLV	24.90
27	43,608	Rail/Barge	16.94	Pipe/Barge	15.61	Pipe/Barge	17.32	Rail/Barge	22.34
28	23,834	Rail/Ship/ GLV	19.05	Pipe/Truck	15.55	Rail/Ship/ GLV	22.91	Rail/Ship/ GLV	22.91
29	50,403	Rail/Barge	20.35	Pipe/Barge	19.60	Pipe/Barge	21.31	Rail/Barge	26.33
30	12,891	Rail/Ship	11.15	Pipe/Ship	8.04	Pipe/Ship	9.74	Rail/Ship	14.89

Exhibit 10.9: Transportation Costs for Supply Region 9 - Alabama (York, AL)

		Solid Fuel Forms		Syncrude Fuel Forms		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
I. Demand Regions Not on Navigable Waterways									
1	2,672	Truck/Barge/ Ship/Rail	20.17	Pipe	13.03	Truck/Barge/ Ship/Rail	18.15	Truck/Barge/ Ship/Rail	18.15
2	14,475	Truck/Barge/ Ship/Rail	23.00	Pipe	13.03	Truck/Barge/ Ship/Rail	20.71	Truck/Barge/ Ship/Rail	20.71
3	50,150	Rail	15.35	Pipe	7.17	Rail	27.59	Rail	27.59
4	58,359	Rail	9.81	Rail	14.94	Pipe	11.44	Rail	14.94
5	12,369	Rail	15.71	Pipe	10.38	Rail	24.30	Rail	24.30
6	31,893	Rail	14.69	Pipe	7.37	Rail	22.35	Rail	22.35
7	2,379	Rail	18.51	Pipe	14.35	Rail	31.78	Rail	31.78
8	20,039	Rail	18.07	Pipe	9.12	Rail	31.40	Rail	31.40
9	11,473	Rail	23.79	Pipe/Truck	38.03	Rail	45.32	Rail	45.32
10	17,537	Rail	24.96	Pipe/Rail	22.69	Rail	46.97	Rail	46.97
11	5,920	Rail	29.88	Pipe/Truck	15.09	Rail	63.37	Rail	63.37
12	4,550	Rail	31.28	Pipe	31.65	Rail	66.12	Rail	66.12
13	4,989	Rail	33.15	Pipe	30.42	Rail	71.33	Rail	71.33
14	2,609	Rail	33.34	Pipe	13.09	Rail	72.98	Rail	72.98
15	5,709	Rail	39.44	Rail	88.82	Rail	88.82	Rail	88.82

Exhibit 10.9: Transportation Costs for Supply Region 9 - Alabama (York, AL)
(continued)

		Solid Fuel Forms		Syn crude Fuel Form:		Methanol		Coal Slurry	
Demand Regions	1985 Coal Consumption (1000 Short Tons)	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton	Primary Mode	\$/Short Ton
II. Demand Regions on Navigable Waterways									
16	18,879	Truck/Barge/Ship	12.32	Truck/Barge/Ship	10.03	Truck/Barge/Ship	10.03	Truck/Barge/Ship	10.03
17	9,369	Truck/Barge	10.96	Truck/Barge	9.13	Pipe	2.60	Truck/Barge	9.13
18	17,325	Truck	6.53	Truck	4.29	Truck	4.29	Truck	4.29
19	9,951	Truck/Barge	11.92	Truck/Barge	10.85	Truck/Barge	19.85	Truck/Barge	10.85
20	10,605	Truck/Barge	9.29	Truck/Barge	8.36	Truck/Barge	8.36	Truck/Barge	8.36
21	19,143	Truck/Barge	14.85	Truck/Barge	14.47	Truck/Barge	14.47	Truck/Barge	14.47
22	8,967	Truck/Barge	11.57	Truck/Barge	11.02	Truck/Barge	11.02	Truck/Barge	11.02
23	6,098	Truck/Barge	13.81	Truck/Barge	13.63	Truck/Barge	13.63	Truck/Barge	13.63
24	2,167	Truck/Barge	11.60	Truck/Barge	11.06	Truck/Barge	11.06	Truck/Barge	11.06
25	3,946	Barge/Ship/GLV	20.10	Barge/Ship/GLV	17.92	Barge/Ship/GLV	17.92	Barge/Ship/GLV	17.92
26	16,081	Barge/Ship/GLV	21.41	Barge/Ship/GLV	19.23	Barge/Ship/GLV	19.23	Barge/Ship/GLV	19.23
27	43,608	Truck/Barge	10.22	Truck/Barge	9.44	Truck/Barge	9.44	Truck/Barge	9.44
28	23,834	Barge/Ship/GLV	19.42	Barge/Ship/GLV	17.24	Barge/Ship/GLV	17.24	Barge/Ship/GLV	17.24
29	50,403	Truck/Barge	13.63	Truck/Barge	13.42	Truck/Barge	13.42	Truck/Barge	13.42
30	12,891	Truck/Barge	11.51	Truck/Barge	9.21	Pipe/Ship	6.24	Truck/Barge	9.21

**Exhibit 11.1 Distribution of Shipping Costs for Solid New Fuel Forms:
Northwest Supply Region**

**Exhibit 11.2 Distribution of Shipping Costs for Solid New Fuel Forms:
Powder River Supply Region**

**Exhibit 11.3 Distribution of Shipping Costs for Solid New Fuel Forms:
Fort Union Supply Region**

**Exhibit 11.4 Distribution of Shipping Costs for Solid New Fuel Forms:
South Wyoming Supply Region**

**Exhibit 11.5 Distribution of Shipping Costs for Solid New Fuel Forms:
Denver Basin Supply Region**

Exhibit 11.6 Distribution of Shipping Costs for Solid New Fuel Forms:
Rocky Mountain Supply Region

**Exhibit 11.7 Distribution of Shipping Costs for Solid New Fuel Forms:
San Juan Supply Region**

**Exhibit 11.8 Distribution of Shipping Costs for Solid New Fuel Forms:
Texaria Supply Region**

**Exhibit 11.9 Distribution of Shipping Costs for Solid New Fuel Forms:
Alabama Supply Region**

**Exhibit 12: Median Shipping Costs for Solid New Fuel Forms
(\$ per Short Ton)**

Supply Region	Demand Regions			Total - All Demand Regions
	Not On Navigable Waterways	On Navigable Waterways		
Northwest	36	25		29
Powder River	24	25		24
Fort Union	20	23		21
South Wyoming	24	25		25
Denver Basin	21	21		21
Rocky Mountain	24	23		23
San Juan	25	23		24
Texarla	17	18		17
Alabama	15	13		14

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