

6.6 Comparison with WTI Model

An attempt was made to compare the cost model used in this report (hereafter referred to as the "UMC Model") with one used by the Williams Technologies, Inc. (hereafter referred to as the "WTI Model"). The two models were compared for four scenarios (1, 15, 17 and 21). In each case, results were compared for four different pipeline lengths (100, 300, 700 and 950 miles), each at four different coal throughputs (3, 5, 10 and 20 MT/yr). Results of this comparison are given in Appendix VI.

It can be seen from Appendix VI that the UMC Model and the WTI Model yield approximately the same first-year costs. However, they yield quite different results for the average present-value unit cost, U_0 . The WTI model yields values of U_0 almost twice as high as those calculated from the UMC Model. This is due primarily to three reasons.

- (1) In the WTI model, the first-year pipeline tariff was escalated at 2% to offset operational cost increases. In the UMC model, the CLP tariff increase for each year was also determined by balancing the operational cost of each year with the revenue generated. However, as shown in the last column of Table 15, the present value of the CLP unit cost, U_p , increases at a rate that is different for each year. The average is approximately 3.4%. This means the UMC Model allows the pipeline tariff to rise from its first-year value at an average annual rate of 3.4% which is higher than that assumed in the WTI model.

- (2) The UMC Model assumes an 8% rail tariff escalation rate when the general inflation is 6%. This allows the UMC Model to discount at 8%. In contrast, the WTI model assumes that rail tariff will increase only at 2.4% each year.
- (3) The WTI Model assumes that the CLP can be used for 20 years only; the UMC Model assumes that major components of CLP can be used for 30 years.

All the foregoing three assumptions made by WTI are much more conservative than those made in the UMC Model. Together they resulted in a much higher value of U_0 and F than calculated from the UMC Model. It is the opinion of the writers of this report that the WTI Model, which reflects how pipeline tariffs are normally determined by the pipeline industry, is overly conservative. It does not yield the most accurate determination of the economic value of CLP as compared to other modes of transports. The UMC Model, which is patterned after the OTA Model [4], yields less conservative but more realistic results.

assumption

7. SLURRY PIPELINE COSTS

Slurry pipeline is a time-honored method for transporting minerals, including coal, over various distances. Table 1 in Appendix I lists the major slurry pipeline built around the world. The most noteworthy is the Black Mesa Coal Slurry Pipeline--an 18-inch-diameter pipeline that transports 5 million tons of coal per year from Black Mesa, Arizona to the Mohave Power Plant in Southern Nevada, over a distance of 273 miles. The pipeline has been operating since 1970 without major problems--a success story of coal pipelines.

A detailed cost analysis on coal slurry pipelines was published in 1978 by the Office of Technology Assessment (OTA), U.S. Congress [4]. It constitutes the most rigorous and reliable cost analysis ever performed on coal slurry pipelines. To take advantage of the myriad data contained in this OTA report, cost figures for coal slurry pipelines needed in the present study were taken from the OTA report with proper adjustments for inflation between 1978 and 1992. According to Engineering News Records [13], from 1977 to 1992, construction costs increased by a factor of 1.93. During the same period, equipment cost increased by a factor of 1.87 [14], and consumer price increased by a factor of 2.28 [17]. These factors were used in adjusting the 1977 costs reported in the OTA report to the 1992 costs used in this report.

The 1992 costs for various components of a typical coal slurry pipeline system are given in Appendix III-I. These costs figures were used for calculating the unit cost to transport coal by slurry pipeline in the same manner as for CLP discussed before. The final results for slurry pipeline, again in terms of unit cost as a function of distance and throughput, are given in Fig. 36 for the same six throughputs as that of CLP in Fig. 4 for scenario 1. From Fig. 36, in general the unit cost of transporting coal by slurry decreases with increasing distance and throughput in a manner similar to CLP. Comparison between Fig. 36 and Fig. 4 shows that the unit costs of CLP are significantly below those of coal slurry pipelines, especially when the distance is short. The fact that CLP can transport coal more economically than slurry pipeline can especially at relatively short distances is significant. This gives CLP a much larger market than slurry pipeline has for coal transportation. Further comparison between coal slurry pipeline and CLP will be discussed later in Section 9. COMPARISON OF RESULTS.

8. TRUCK AND RAIL COSTS

Transportation of coal by truck is expensive and it is done usually over short distances only. Coal trucking may be classified into two kinds: (1) mine-to-tipple trucking which has an average distance of 5 to 10 miles, and (2) mine-to-market trucking which moves an average distance of about 50 miles. Trucking coal over a distance greater than 100 miles is uncommon.

The cost for trucking coal varies greatly with transportation distance and the size of the truck. For mine-to-tipple trucking (up to 10-mile distance), very large tractor-trailers may be used to reduce cost. However, these trucks are allowed only on private roads owned by coal companies or utilities that own the coal mines; they are not allowed on public roads. For distances greater than approximately 10 miles, public roads are normally used, and the size and the weight of the coal trucks are limited by state law or county statutes.

Using information contained in [7, 18, 19] and using 1991 cost data for truck supplied by the Missouri Department of Highway and Transportation*, curves were derived to show the variation of the unit cost for transporting coal by truck--see Fig. 37. Comparison of Fig. 37 with Fig. 4 shows that coal transportation by CLP is

* Truck rates are regulated in Missouri. The state sets the maximum and minimum rates for different types of freights and distances.

always more economical than by truck except for small throughput and very short distances. For instance, for throughput greater than 2 MT/yr, transportation by CLP is always more economical than by truck whenever the distance is longer than 30 miles, approximately.

For comparison purpose, Fig. 37 also contains curves (dotted lines) for the costs of transporting coal by unit train. Note that unit train is the most cost-effective way to transport coal by rail. Each unit train consists of approximately 100 cars carrying only coal. The train travels non-stop between power plants and coal mines. From Fig. 37, trucking coal is more expensive than shipping coal by unit train except for distances shorter than approximately 50 miles. The reason that trucks are often used for distances greater than 50 miles is that many power plants are not served by railroads. To build new railroads to transport coal to power plants is normally rather expensive. The cost for unit train transport shown in Fig. 37 is based on the use of existing railroads.

The curves for unit train (dotted lines in Fig. 37) were derived from Fig. 17 of Reference [4] by averaging the cost of several lines, and then adjusting the average to 1992 costs by using a rail cost escalation index of 2.48 (from 1977 to 1992) published by the U.S. Bureau of Labor Statistics [20]. The calculated costs include a 12.5% profit. The data points in Fig.

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37 were obtained from Coal Transportation Report [21]; they represent tariffs charged by different railroads. The spread of data shows the variation of costs with regions and routes. The lower points apply to the western region of the United States. Figure 37 shows that the tariffs charged by most rail companies are below their costs with a 12.5% profit. This means due to competition, many rail companies may be operating with less than 12.5% profits. Most railroads may not be able to further reduce their profit margin or continue to maintain a tariff escalation rate below the general inflation rate without starting to lose money. Whether this is true or not should be verified in a future study.

more
study

9. COMPARISON OF RESULTS

It is desirable to compare the unit cost of coal transport by CLP with those of truck, unit train and slurry pipeline. This can be done for each of the scenarios investigated. Comparison of Scenario 1 (standard case) with truck and train shows that there is a wide range, especially when throughput is high and distance is long, that CLP is more economical than train and truck. Comparison with slurry pipeline shows that it is always more economical to transport coal by CLP than by slurry pipeline, especially when the distance is short.

In the comparison of the unit cost of coal transport by CLP to that of train and truck, three factors favoring CLP were ignored. The first is that coal logs containing binders such as asphalt have a higher heating value than coal. This additional heating value ~~was~~ not considered in calculating the unit cost which is based on the cost per ton of logs rather than per Btu. The second factor is water content in coal. Coal transported by train from the Powder River Basin in Wyoming contains close to 30% water. The fabricated coal logs, on the other hand, normally have less than 15% water. With logs treated for sealing, no water is absorbed into the logs during transport. This means the transported logs have 50% less water than the raw coal, and hence a higher heating value. A third factor ignored is that costs were compared based on equal distance. However, while slurry pipelines and CLP normally follow a

straight-line distance between a coal mine and a power plant, the same is not true for truck and rail. They often follow a route more than 20% longer than the straight-line distance taken by pipelines.

Finally, it should be realized that the aforementioned comparisons use scenario 1 which is not based on the optimal conditions of CLP. Future research in CLP will undoubtedly bring about technological advancements that will result in reduced costs for CLP. As can be seen by comparing scenarios 1 with 17, as much as 30% saving is possible when drag-reducing additives are used in long pipelines.

In passing, it should be realized that the emerging new technology of CLP not only has great economic values established through this study, it also has environmental and other practical advantages such as the following:

- (1) CLP uses only one-third to one-fifth of the water used by a coal slurry pipeline to transport the same amount of coal. This water-saving feature makes CLP more acceptable than the coal slurry pipeline for transporting coal from arid or semi-arid regions such as Wyoming and Colorado. At present, there is a great demand in the Midwest and the Southern states for the low-sulfur coal from Wyoming.
- (2) Due to the small amount of water used in CLP, the technology can use treated (desalted) brackish water and still be economically competitive.
- (3) Because the solid-liquid contact surface area for coal logs is several orders of magnitude smaller than that for coal slurry, contamination of water by coal logs is much less than by coal slurry.

- (4) The land requirement for coal log terminal at power plants is much less than for slurry terminal. Besides, it is much easier to store logs than to store slurry at power plants.
- (5) Coal logs are a more versatile form of fuel than coal slurry. After crushing, the logs can be burned in stoker, fluidized-bed, pulverized-coal, and cyclone-type combustors.
- (6) Coal logs can be transported not only by pipelines but also by trucks, trains, ships and conveyor belts. It is a new form of coal-based fuel that can be easily stored, handled and transported by various modes of transportation without causing coal dust problems. In contrast, coal in powdered form causes severe coal dust problems during handling, storage and transportation by truck, train and ship.
- (7) Coal logs can be easily loaded on conventional ships for export. To export conventional coal slurry which contains 50% water, not only special ships are required, 50% of the weight transported will be water instead of coal.
- (8) Pulverized coal transported by ships often causes spontaneous combustion and fire hazards. In contrast, the voids that exist between coal logs stored in a ship facilitate air circulation and prevent build-up of heat. Consequently, fire hazards are reduced with ships carrying coal for logs for export.
- (9) Coal log pipeline can restart easily after any periods of shutdown. It has no restart problem which a coal slurry pipeline may have.
- (10) When pipelines (CLP or slurry) are used to replace trucks and trains for transporting coal, the public benefits from reduced air and noise pollution caused by trucks and trains, reduced traffic jam and accidents on highways and streets, reduced derailment, reduced interruptions of traffic at rail crossings, reduced damage to highway and bridges by trucks, reduced consumption of imported oil, and saving of numerous lives (both human lives and animals) killed each year on highways (by coal trucks) and on railroads (by unit trains).

10. CONCLUSIONS

Based on the foregoing analyses, the following conclusions are reached:

- (1) Comparison with conventional coal slurry pipelines that transport 50:50 slurry (coal-water ratio by weight) indicates that CLP is significantly more economical than coal slurry pipeline especially when the transportation distance is relative short, say less than 100 miles. This gives CLP a much larger market (window of opportunity) than coal slurry pipeline has on economic grounds alone. The fact that CLP uses much less water and conveys more coal than slurry pipeline also favors CLP.
- (2) Comparison with truck reveals that it is always more economical to transport coal by CLP than by trucks except for very short distances and at low throughputs. For instance, for throughputs of 2 MT/yr or above, CLP is more economical than truck whenever the distance is above 30 miles, approximately.
- (3) Comparison with unit trains that use existing rails reveals that while at low throughputs (less than 1 MT/yr) it is difficult for CLP to compete with such trains, the opposite holds at high throughputs. For instance, at 18 MT/yr which requires a 20-inch-diameter CLP, the cost for transporting coal by CLP is less than by rail for any distance ranging from 10 to 2,000 miles.
- (4) The use of binder in making coal logs, if required, would be costly. Even with asphalt which is one of the least costly binders, each 1% binder (by weight) increases the cost of coal logs by one dollar per ton, approximately. Using more than 3% binder renders the CLP technology uneconomical when competing with rail, truck and slurry pipeline. Therefore, minimizing or eliminating the use of binder is imperative in the R & D of CLP.
- (5) Even though desalinated brackish water is several times more expensive than fresh water, using the desalinated water instead of fresh water to transport coal logs by CLP only increases the cost of coal log transport slightly--about 15¢ per ton of coal transported. This is good news because whenever fresh water is unavailable for a given CLP project, as may happen in Wyoming, one can consider brackish water and still have an economically

viable project. The same cannot be said for coal slurry pipelines which require more water and have a much smaller profit margin.

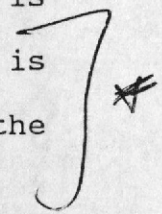
- (6) The use of drag reducing additives such as polyethylene oxides and/or fiber (pulp) may cause great savings in the energy required for CLP, and this has a strong impact on the unit cost of CLP when the pipe is long. For a 1,000-mile pipeline, more than \$3.00 per ton might be saved from using such additives. Experiments are needed to substantiate the effectiveness of such additives for use in CLP.
- (7) It is more economical to transport light logs (say $S = 1.05$) than heavy logs (say $S = 1.35$) over long distances. This is due to the lower lift-off velocity of light logs, and the resultant lower energy consumption. On the other hand, for short pipelines with light logs the reduced throughput outweighs the energy savings. Therefore, while heavy logs are better suited than light logs for short pipelines, lighter logs are more suitable for long pipelines.
- (8) Using a pig (special capsule) to lead each long coal-log train for spacing control and pipe cleaning increases the coal transportation cost only slightly. This means the use of such pigs can be considered if their use improves system reliability.
- (9) The economic advantage of using an existing pipeline instead of constructing a new pipeline for CLP may not be evident due to the short economic life of the existing pipe. However, if a decommissioned or about-to-be-decommissioned pipeline exists along a certain route of coal transport, and if the pipeline can be renovated as by providing an insert, the system can be quite economical and can avoid the lengthy delay caused by the right-of-way acquisition of a new pipeline.
- (10) The use of deaeration equipment at CLP inlet increases unit costs only slightly. It can be justified for all CLP systems as a means to fight internal corrosion.
- (11) It is economically unjustifiable to use a duplicate CLP intake lock system and a duplicate pump bypass if their use increases system reliability (availability) by only 5%. A higher gain in system reliability is required to justify such duplicate systems.
- (12) In many situations, companies investing in CLP can expect a high profit rate (say, a 30% annual return) and still

be able to offer a tariff competitive with other modes of transport.

- (13) The equity rate has little effect on the unit costs of CLP.
- (14) The discount rate has a profound effect on the unit costs. Approximately, a 1%-point increase in the discount rate reduces unit costs by 10%.
- (15) The inflation rate and energy escalation rate also have a profound effect on unit costs. Approximately, a 1% increase in each of these two rates produce the same result as a 1%-point decrease in the discount rate. Therefore, a 1%-point increase in inflation and energy escalation rates can be balanced approximately by a 1%-point increase in the discount rate.
- (16) Meaningful analyses require that the discount rate be tied to the inflation and energy escalation rates. A higher inflation rate requires a higher discount rate and so forth.
- (17) To compare the average present values of unit costs with the current rail tariffs, the discount rate used must be the rail tariff escalation rates anticipated for the next 30 years. This is expected to be higher than the general inflation rate.

11. RECOMMENDATION FOR FUTURE STUDY

This study shows the potential economic value of CLP transportation of coal as compared to truck, unit train, and slurry pipeline. However, such economic potential cannot be realized without further research and development. The most needed research is to improve coal log fabrication means so that coal logs can be made with less than 3% binder, or no binder at all. The logs produced must be strong enough to resist long-distance transportation through pipelines. Another innovation that would greatly reduce the cost of CLP is to use drag reducing agents--polymers, pulp, or a combination of both. Research to assess the effectiveness of using such drag-reducing additives is overdue and should be conducted immediately. Finally, research is needed to assess the cost of operating railroads and the anticipated long-term rail tariff increase.



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