TECHNICAL RISK AS A COST FACTOR IN COAL LIQUEFACTION: SOME FINANCIAL CONSIDERATIONS

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INTRODUCTION

The U. S. economy is fueled largely by liquid fuels obtained, in no small measure, from unstable sources. The litany of wars, embargoes, and sudden price hikes implies that developing alternative indigenous supplies of liquid fuel is a national economic security issue. Liquid fuels derived from coal are among the alternatives available.

Coal liquids must replace petroleum products in existing applications when they enter the marketplace. That point of entry is almost unique [1-3]. Coal liquids must replace oil directly, for domestic oil supplies are declining. This is also unique in the energy supply history of this country [4-5]. Thus the entry of coal liquids into the economy is fraught with uncertainties caused by unusual conditions.

Uncertainties in the marketplace exist; however a technical base for the development of a coal liquids industry has been developed. Generically four approaches have been pursued: pyrolysis, solvent extraction, catalytic hydrogenation, and indirect liquefaction. Of these, indirect liquefaction is being practiced commercially in countries outside the United States [6].

The existence of a technical base does not imply that coal liquefaction is a mature technology. Rather, it shows that there is a significant gap between what is technologically available and what is economically available. This gap can be attributed to the efficiencies, the capital costs, and the financial risks of such systems. Those financial risks are substantially influenced by the magnitude of the investments and the status of the technology.

This financial gap has not always been recognized in the literature. In order to show the influence of this risk-related issue on coal liquefaction costs and market potentials, the following

considerations are addressed here: (1) a review of previous cost estimating practices, (2) an evaluation of U.S. investment practice related to innovative processes, and (3) the influence of those factors on the costs of coal liquids.

In 1976 a major coal liquids economics symposium was held by the American Chemical Society. In this symposium a common set of economic assumptions were employed. The 1976 ACS symposium, and the values in Table 1 used in that meeting, represents a major step in unifying coal liquefaction economics. However these assumptions do not lead to a solid financial analysis of coal liquefaction plants, and for the following reasons: (1) they intertwine the "what to finance" with "how to finance" decisions; (2) they mask the fact that cash flow, not profit, supports a corporation; and (3) they do not incorporate the influence of technical risk into the discount rate.

The first defect argues that corporations will view new technologies with the same investment ground rules as existing technologies. Corporations are risk averse, however, and prefer to invest in improved existing systems rather than higher risk new systems [8]. Higher rates of discount are required to attract capital into new projects. The second and third deficiencies are violations of the principles of financial analysis [10]. The use of any or all of these three assumptions leads to overly optimistic product cost values.

Given these problems, it is useful to reexamine the discount rate used in calculating coal liquid costs, adjust the accounting procedures to separate "what to finance" from "how to finance," and analyze costs in a way to maximize cash flow. With these adjustments, order of magnitude price estimates may be made and, more importantly, the influences of risk and experience on product costs can be made.

THE DISCOUNT RATE AND COAL LIQUID COSTS

The nominal discount rate is composed of three elements as shown in formula (1):

$$DR = I + M + R \qquad (1)$$

Where I = the inflation rate, M = the riskless cost of money (sometimes referred to as the premium for early availability of funds), and R = the premium for total investment risk [10]. Risk can be broken down further into several components as shown in formula (2):

$$R = f(R_e, R_b, R_f, R_t) \qquad (2)$$

Where R_e = economic risk (e.g., the risk of a recession), R_b = business

risk, R_f = financial risk (e.g., degree of leverage) and R_t = technological risk. For most firms, the R_e term is uncontrollable and is not isolated. R_t is usually subsumed in business risk if no major innovation is contemplated, where the major innovation will influence the capital structure.

Calculating the Discount Rate

Each major industry has its own appropriate nominal discount rate reflecting the financial investments of debt and equity participants in that industry. While several models exist for calculating the discount rate, the Modiglani-Miller (M-M) theorem is sufficient for these purposes. The model is shown in equation (3) from Haley and Schall [11].

$$DR = \theta K_d + (1 - \theta) K_e \tag{3}$$

Where θ = the proportion of debt, K_d = the cost of debt (including tax effects) and K_e = the cost of equity capital. K_d is taken as the yield-to-maturity on bonds multiplied by 1-TR where TR = the Tax Rate, fractional basis. K_e can be calculated by several techniques varying in sophistication. Again, due to the imprecise nature of discount rate estimation in the face of technological risk, the simplistic approach is taken here and shown in formula (4).

$$K_e = D/P + G \tag{4}$$

Where D = expected dividends, P = stock price, and G = the expected growth rate of the (stock) investment over its useful life.

The M-M model applies to traditional investments and is based upon the principle that, while increasing the debt fraction decreases the apparent discount rate, it increases the degree of leverage, the financial risk and hence the cost of equity capital. Based upon the above equations, Tables 2 and 3 are presented, giving the estimated discount rates for Gulf, Exxon, and Mobil Oil. Growth estimates are based on 10-year earnings/share ratios. For subsequent analysis, the nominal rate of 15% is used since it shows the approximate 1:3 debt/equity ratio common to the energy industry [12] and is the median case calculated.

Table 2 presents the capital structure for Exxon, Gulf, and Mobil--the three companies chosen to develop the discount rate for this industry. Significant is the absence of preferred stock in these companies. Also significant to note is that there is heavy reliance on common stock. Thus the growth issue arises; and it is

complicated by varying expectations concerning the decontrol of petroleum prices.

The Influence of Risk on the Discount Rate

The financial literature is replete with citations concerning the influence of business and financial risk on the discount rate. The typical relationship shown is essentially linear and is referred to as the "Security Market Line" shown in Fig. 1.

Technical risk and/or uncertainty is less well-treated in the literature than busines/financial risk. Technical risk, however, is critical to new energy investment evaluation [13]. Its influence can be evaluated by analogy to traditional business/financial risk assessments.

Empirical studies have addressed the risk issue, including reports by technical Micro Economic Associates [14] and Robert R. Nathan Associates [15]. The former deals largely with the influence of risks on supplies and prices; and the latter shows rates of return obtained on innovations in U.S. industry since 1940. Pre-tax private internal rates of return (IRR) ranged from negative to 157% over a broad spectrum innovations on a real dollar basis.

Two petroleum industry innovations, one in extraction and one in processing, showed pre-tax IRR values of 50 to 56% in the Nathan Associates study. This is slightly higher than the median value of 34 to 38%. Given standard economic assumptions, after tax rates of return can be calculated at ∿20% on average and ∿30% in the petroleum industry. It should be noted that the petroleum related investments were made in 1942 and 1949. However, a mining related innovation introduced in 1964 had a pre-tax IRR of 54%. These IRR values are not discount rates per se, but they give some clue to investor expectations. Thus, resource industry innovations may generally require the higher discount rates.

The risk-adjusted discount rate also is a function of some learning curve concerning the new technology. Those extractive industry innovations which first earned ∿30% after taxes now require ∿15%. The initial parts of the investment learning curve, both technically and financially, relate to the process of going from concept development and bench scale research to commercial technologies through process development units and then pilot plants. Swabb [16] identifies the preferred succeeding step from pilot plant to commercial technology as a pioneer plant, to be owned and operated by the private industry as a commercial facility followed by the design and construction of succeeding commercial plants. The pioneer plant

is critical in this approach as it demonstrates plant reliability, product output, environmental protection safeguards, and commercial viability. It reduces business risk to manageable levels.

If one accepts the Schwabb argument, then the discount rate for the pioneer plant may be nominally ∿30%. The lower limit is, of course, nominally 15%. The upper limit, however, remains essentially undefined. Further, the number of commercial plants required to go from 30% to 15%, is also undefined.

Similar learning curves have been posited for capital cost estimates [17, 18]. Such curves take the form of sensitivity analysis parameters. The analogy between capital cost and discount rate estimation is imperfect, both sets of data deal with investment uncertainties as perceived by boards of directors. Despite these uncertainties, a 30% discount rate is used here for pioneer plants, and a 15% discount rate is used for mature plants.

The empirical technical risk adjustment made here is analogous to an unusual business risk taken. Before the passage of the Public Utility Regulatory and Policies Act (PURPA), industries entering cogeneration ventures perceived the following risks: (1) would they be regulated as utilities; (2) would utilities purchase surplus power from them; and (3) would utilities sell them power as needed at a reasonable cost. Frequently after-tax rates of return demanded by cogenerators were 30% [19]. Again it is an imperfect analogy. The investment community is consistent--manufacturing industry. The broad investment arena is energy. The cogeneration technology, however, is mature. Thus this risk adjustment is only one more indicator of investor behavior.

CALCULATED COSTS OF COAL LIQUIDS UNDER UNUSUAL AND NORMAL RISK CONDITIONS

Remaining are the tasks of estimating the initial costs of coal liquids and the price reductions possible as investor corporations gain commercial experience in coal liquefaction. Accomplishing these evaluations requires making some accounting assumptions. It then involves calculating fuel costs based on the systems selected.

Accounting Conventions and Assumptions

In the projecting of synthetic fuel costs, certain conventions play an important role: (1) the selection of a depreciation method; and (2) the selection of a dollar basis.

Three depreciation methods exist: straight line, sum-of-the years digits, and double declining balance. In general, the latter two accelerated systems generate more favorable cash flows (depending upon the capital strucutre of the industry). The double declining balance method generates particularly high depreciation values in the first few years. Thus, it is used here.

Depreciation may be taken over a variety of time periods. To maximize cash flow, and the contribution of depreciation to net present value, the shortest possible depreciation period is preferred. The Internal Revenue Service [20] gives a minimum of 13 years for petroleum refineries; and this value is assumed to hold for coal liquefaction plants.

Depreciation is the major area of capital recovery meriting documentation. Historical statistics can be used to develop assumptions for cost increases over time. These are shown in Table 4. These values are used in constructing proforma statements.

System and Product Costs

Two systems have been selected for analysis here: (1) methanol synthesis and (2) solvent extraction. Methanol is advanced frequently as a technology of immediate application [21, 22]. Solvent extraction is considered one of the leading candidates for boiler fuels production [23]. Both systems are described generically in Sliepcevich et al. [24]. Table 5 presents the significant capital cost and product output parameters for each unit. The cost values have been updated to 1980 dollars from the original publication by use of the chemical engineering plant cost index as reported in the Engineering News Record [25].

Both the methanol and solvent extraction plants were estimated to cost $\$1 \times 10^9$ in 1977, and are now estimated to cost $\$1.3 \times 10^9$. After removal of the 20% investment tax credit, these capital costs are $\$1.04 \times 10^9$. If one assumes a 13-year amortization period, the risky investment with a discount rate of 30% must generate an annual after-tax cash flow of $\$322 \times 10^6$. If the technology were considered by investors to be mature, that after-tax cash flow requirement would be $\$178 \times 10^6$. The differential is particularly significant since investment tax credits and depreciation are calculated without regard to technological matury. Thus the $\$144 \times 10^6$ must be made up entirely with after-tax profits.

From these data, modified proforma statements have been constructed for both technologies assuming: (1) instantaneous construction and startup and (2) constant after-tax cash flows. These

are optimistic assumptions but they do not affect the analysis of financial risk reduction seriously, since they are constant relative to the variable discount rate. Table 6 is the proforma statement for selected years of the risky solvent extraction plant. Table 7 is the proforma statement for the same years assuming a mature technology. Values are in nominal (inflated) dollars.

It is significant to note that the high risk plant must be profitable from the start. The mature plant can sustain losses during the first year without jeopardizing the cash flow stream. Depreciation is for more significant to the mature plant than the high risk pioneer plant. Similar proforma statements can be constructed for methanol plants. Revenue streams can then de deflated to 1980 dollars by the following formula:

$$D_t = 1.064^t \tag{8}$$

Where D = deflator and t = the year of operation. From these values Table 8 is constructed showing the approximate cost of fuels from pioneer plants and mature plants. In both cases the gaining of financial experience carries a cost savings of about $10/bbl of oil equivalent.

What is significant here is not the $40/bbl or $60/bbl value. These are best guesses based upon available information from pilot plants. Nobody knows what coal liquids will actually cost. Rather, it is the cost reduction associated with investor experience which is significant. Cost savings of $1-2/10^6$ Btu are substantial. These result from a reduction in the discount rate as risks and uncertainties are reduced.

CONCLUSION

Substantial fuel cost savings, then, are available from corporation investment experience in coal liquefaction facilities. These savings are in the vicinity of $10/bbl or $1-2/10^6$ Btu. These savings also should be pursued. These substantial price reductions may be achieved when investors advance along their own learning curve. That learning curve equates the relationship of expected product price and plant performance to achieved product price and plant performance; and translates that relationship plus market acceptance of the product into a risk factor and an appropriate discount rate. Large savings in fuel costs can be achieved only when investors have advanced sufficiently to reduce their perceptions of liquefaction risk and uncertainty.

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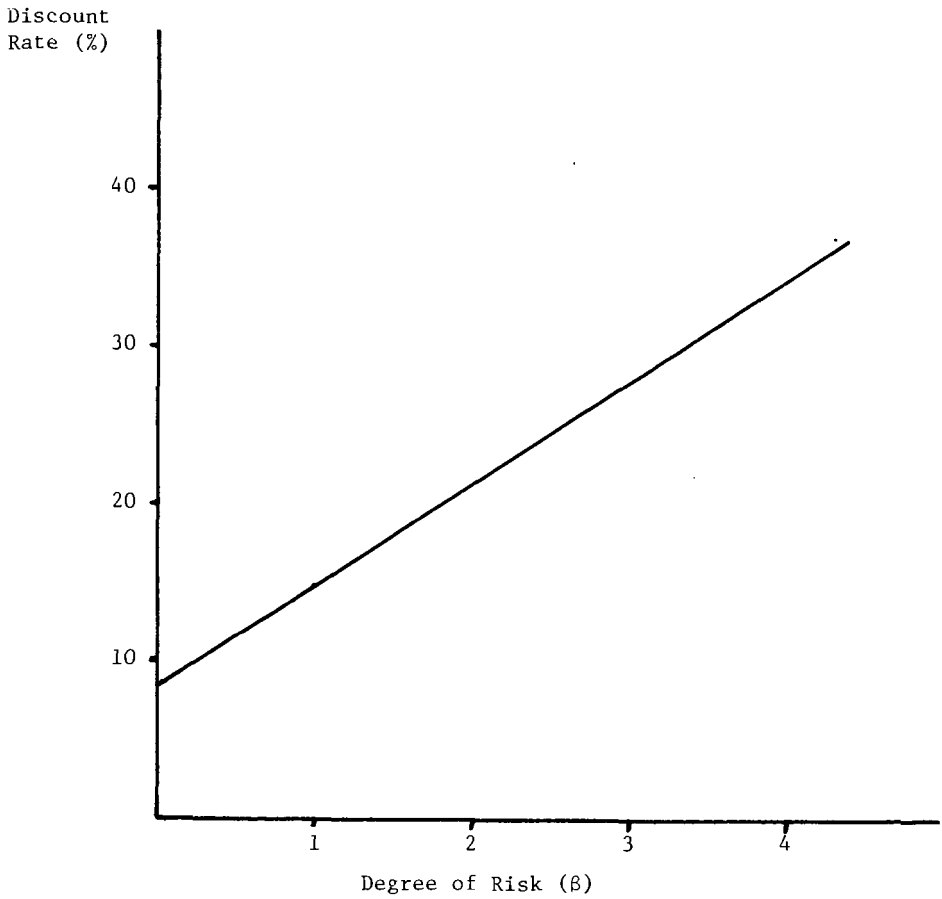

Figure 1. The discount rate, or cost of money, as a function of the degree of risk associated with the investment. This curve is known as the Security Market Line.

TABLE 1. Financial Assumptions for the 1976 American Chemical Society Meeting on Synthetic Fuel Economics

Parameter	Value
Project life	20 years
Cost of capital	10 percent
Depreciation	Straight line
Base Return on Investment[a]	15 percent

[a]Not specified but requently used.
Source: [7]

TABLE 2. The Capital Structure of Three Petroleum Companies, 1979

	Company		
Capital Instrument	Gulf	Exxon	Mobil
Debt	.191	.112	.261
Preferred stock	-0-	-0-	-0-
Common stock	.809	.888	.739
Total	1.00	1.00	1.00

TABLE 3. The Cost of Capital for Three Petroleum Companies (in %)

	Capital Cost Contribution by Company		
Capital Instrument	Gulf	Exxon	Mobil
Debt portion	0.97[a]	0.54[b]	1.18[c]
Common equity portion	11.6 [d]	16.3 [e]	14.0 [f]
Total	12.6	16.8	15.2

[a] .191 x .570 x .089 x 100 = 0.97; .089 = Yield to Maturity on bonds.
[b] .112 x .553 x .087 x 100 = 0.54; .087 = Yield to Maturity on bonds.

(Continued next page.)

[c] .261 x .524 x .086 x 100 = 1.18; 0.86 = Yield to Maturity on bonds.

Second term in all above calculations = 1 - TR for domestic operations. Thus the tax effect of interest is accounted for in the discount rate calculation.

[d] $\frac{2.05}{30.75} + .076 = .143; .143 \times .809 = .116$

[e] $\frac{4}{56.5} + .112 = .183; .183 \times .888 = .163$

[f] $\frac{2.40}{42.625} + .135 = .190; .190 \times .739 = 14.0$

General formula for d, e, f, is $\frac{D_e}{P_e} + G = K_{ceq}$ as defined as follows:

The cost of common equity capital is determined by $D_e/P + G_e = K_{ceq}$ where D_e = expected dividend, P = price, and G_e = expected growth and K_{ceq} = capital cost, common equity.

Sources: Annual Reports, 1978; Standard and Poor's Bond Guide, August, 1979; WSJ, August 28; Value Line.

TABLE 4. Real Price Increases 1968-1978

Good/Service	10 Yr Nominal Rate (%)	10 Yr Real Rate (%)
All goods and Services (CPI)	6.4	-0-
Labor		
Utilities	8.4	2.0
Chemical manufacturing	8.3	1.9
Fuels and Energy		
Coal	11.7	5.3
Electricity	9.3	2.9
Supplies		
Chemicals (Industrial)	8.3	1.9
Miscellaneous supplies	6.0	-0.4
Services	7.0	0.6

Sources: U. S. Census Bureau, 1978; U.S. Census Bureau, 1974; U.S. Bureau of Labor Statistics, 1980.

TABLE 5. Cost and Output Parameters for Selected Solvent Extraction and Methanol Plants

Parameter	Technology	
	Solvent extraction	Methanol
Plant size	50×10^3 bbl/day 325×10^9 Btu/day	11,300 tons/day 230×10^9 Btu/day
Thermal efficiency	64%	46%
1977 capital cost total	$\$0.9 - 1.15 \times 10^9$	$\$0.85 - 1.2 \times 10^9$
1977 capital cost/bbl/day	$\$16.5 - 21.5 \times 10^3$	$\$23 - 30 \times 10^3$
Median 1980 capital cost (gross)	$\$1.3 \times 10^9$	$\$1.3 \times 10^9$
1980 investment tax credit	$\$260 \times 10^6$	$\$260 \times 10^6$

Source: [24].

TABLE 6. Pro Forma Statement for the Solvent Extraction Plant 30% Discount Rate (Values in $\$ \times 10^6$)

Cost/Income Stream	Year		
	1	5	13
Revenue	655	988	1677
Operating cost			
Fuel	223	347	841
Labor	6	8	15
Chemicals and supplies	14	18	31
Water and utilities	2	2	3
Maintenance	68	94	177
Taxes and insurance	16	20	37
Depreciation	200	103	27
Earnings before taxes	226	406	546
Income tax (46%)	104	187	251
Net income after taxes	122	219	295
Depreciation	200	103	27
Cash flow	322	322	322

Sources: Table 5 and [24].

TABLE 7. Pro Forma Statement for the Solvent Extraction Plant - 15% Discount Rate (Values in $ x 10^6)

Cost/Income Stream	Year 1	Year 5	Year 13
Revenue	507	731	1411
Operating cost			
Fuel	223	347	841
Labor	6	8	15
Chemicals and supplies	14	18	31
Water and utilities	2	2	3
Maintenance	68	94	177
Taxes and insurance	16	20	37
Depreciation	200	103	27
Earnings before taxes	(22)	139	280
Income tax (46%)	-0-	64	129
Net income after taxes	(22)	75	151
Depreciation	200	103	27
Cash flow	178	178	178

Sources: Table 5 and [24].

TABLE 8. Levelized Fuel Costs for Pioneer and Mature Coal Conversion Plants (in 1980 Dollars)

Coal Liquefaction System	Fuel Cost: Pioneer Plant $/10^6 Btu	Pioneer Plant $/bbl	Mature Plant $/10^6 Btu	Mature Plant $/bbl
Solvent extraction	8	50	7	40
Methanol	10	60	8	50