APPENDIX I DATA AND MODEL USED IN THE DECISION ANALYSIS

This Appendix describes both the structural model and the data used in the decision analysis of the alternative programs (see Chapter V and VI). Section 1 is a tabulation of the data that forms the base case of the decision analysis. Some of the data, such as the demand curves, was derived from the Stanford Research Institute (SRI) Energy Model. The remainder of the data was a[illegible]ssed directly by consultants and members of the Task Force and is considered to represent the best collective judgment of the Task Force at this time.

Section 2 describes the structural model in detail, showing how the components of total net benefit are calculated in the analysis.

Section 3 is a step-by-step calculation of the total benefit of a sample path through the decision tree.

Section 4 is a short discussion of the environmental and socio-economic costs that are considered in the analysis.

A. DATA USED IN THE ANALYSIS

1. Branch Probabilities

The branch probabilities at each chance node in the decision tree are .25, .50, and .25, except for the two nodes representing the state of the oil cartel in 1985 and 1995. The branch probabilities for these two nodes are shown in Figure 28 of the main text.

2. Demand Curve Parameters

Parametric demand curves are used in the analysis to relate the market price to the quantity of foreign and synthetic fuel demanded. The functional form of the demand curve is:

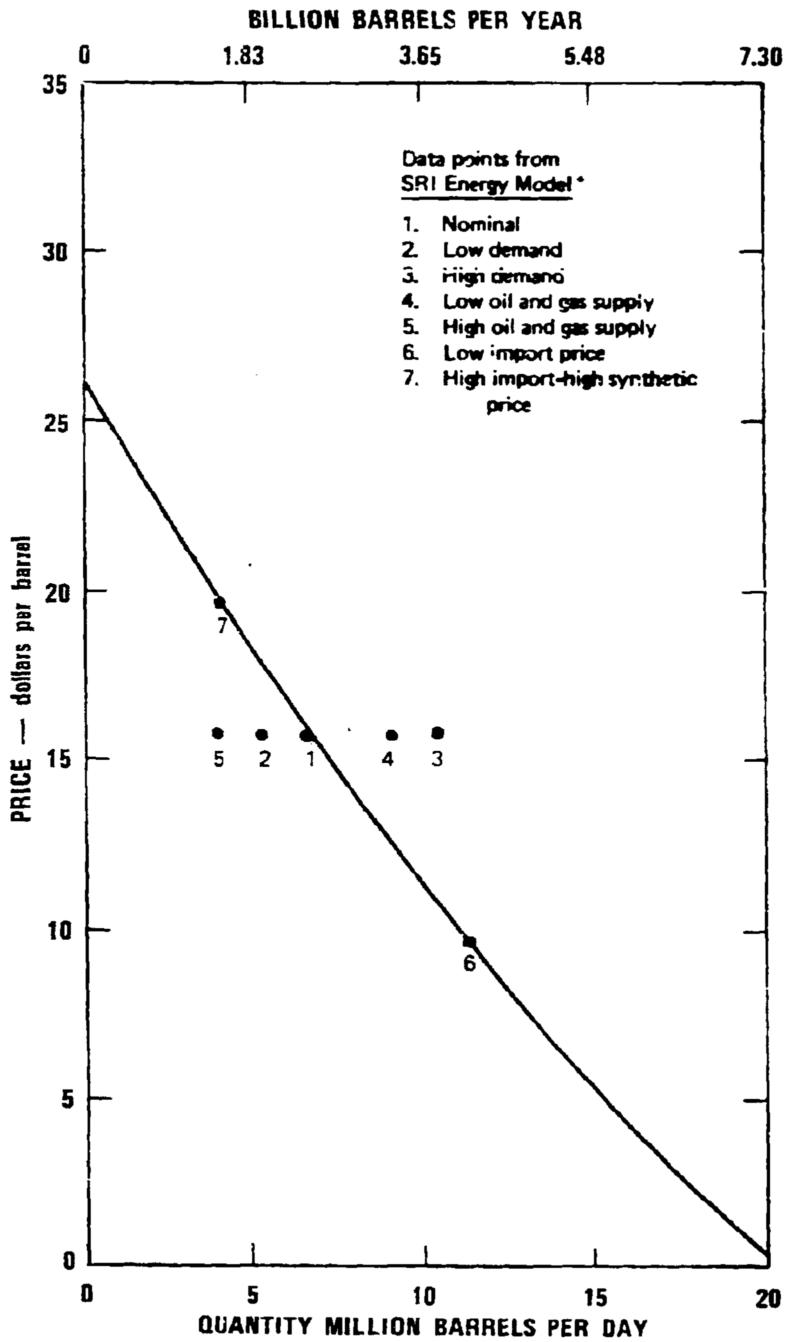
$$p(q) = \frac{a}{b+q} + c.$$

One demand curve is specified for 1985 (shown in Figure I-1), whereas three demand curves (shown in Figure I-2) are specified for 1995 to reflect uncertainty about the U.S. energy position during the 1990's. As shown by the data points on the figures, these demand curves were derived from the SRI Energy Model. The parameters for all four demand curves are given in Table I-1.

3. Synthetic Fuel Production Capacity

The synthetic fuel production capacity in 1985 is assumed to be completely determined by the program decision and is shown in Table I-2. The capacity in 1995 is the sum of the 1985 capacity and the amount by which the capacity is expanded after 1985. The capacity expansion is a private sector decision made in 1985 when the 1985 state of the cartel and the forecast of 1995 synthetic fuel costs are known, but when uncertainty exists about the state of the cartel, the foreign fuel price, the cost of synthetic fuel, and the U.S. energy position in 1995. The private sector decision is made to maximize the expected producer surplus in 1995.

For each combination of program level, state of the cartel in 1985, and forecast of synthetic fuel cost in 1995, the optimal expansion decision is determined within the decision tree analysis. For reference, these optimal expansion decisions are shown in Table I-3.



*SENSITIVITY CASE – APPENDIX H

FIGURE I-1 1985 DEMAND CURVE FOR IMPORTED AND SYNTHETIC FUELS

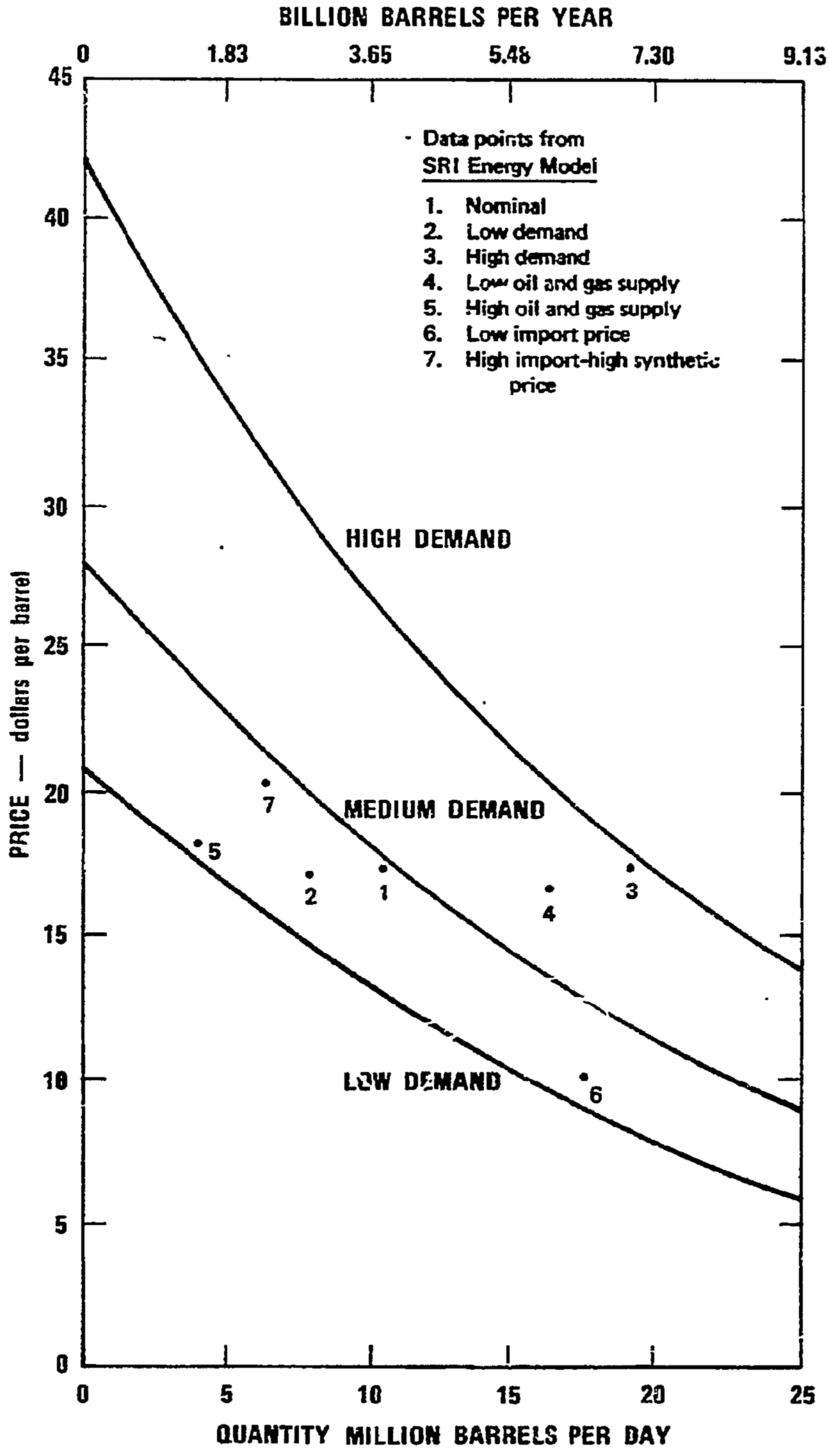


FIGURE I-2 1995 DEMAND CURVES FOR IMPORTED AND SYNTHETIC FUELS

TABLE I-1

DEMAND CURVE PARAMETERS

	a	b	c
1985	1888.875	19.893	-69.000
1995			
Low demand	809.910	18.151	-23.946
Medium demand	809.910	15.596	-23.946
High demand	809.910	12.311	-23.946

TABLE I-2

SYNTHETIC FUEL CAPACITY, 1985 1/

Program Level	Barrels per Day	Billions of Barrels per Year
No program	0	0
Information program	315,000	0.115
Medium program	930,000	0.339
Large program	1,605,000	0.586

1/ Biomass conversion not included. With biomass included, program totals are 350,000 barrels per day, one million barrels per day, and 1.7 million barrels per day.

TABLE I-3

AMOUNT OF CAPACITY EXPANSION

(Millions of Barrels per Day)

Program Level	1985 State of Cartel	Forecast of 1995 Synthetic Fuel Cost		
		Expensive	Moderate	Cheap
No program	strong	0	1	2
	weak	0	0	0
Informational Program	strong	0	2	4
	weak	0	0	2
Medium Program	strong	1	3	4
	weak	0	1	3
Large program	strong	2	4	5
	weak	0	3	4

4. Synthetic Fuel Cost

Regardless of the size of the program, all of the synthetic fuel plants built before 1985 will employ first-generation technology. Therefore, the cost of synthetic fuel in 1985 is independent of program size and depends only on the resolution of uncertainty about the basic technological factors in its production. These costs are shown in Table I-4.

The plants built after 1985 will employ second-generation technology. Because of learning effects, the cost of production in these plants will be generally lower than in the first-generation plants. In addition, the size of the commercialization program will have two effects on the cost of synthetic fuel in 1995. First, because the larger programs explore a more diversified set of technologies and are therefore more likely to develop a low-cost technology to employ in the second-generation plants, the larger the program the lower the expected 1995 cost of production. Second, because the larger programs constitute a larger "sample" of experimental plants, the larger the program the less uncertainty about the 1995 cost of production. Thus, as shown in Table I-4, both the mean and variance of the 1995 cost of synthetic fuel decrease as the program size increases.

The cost of synthetic fuels used in the analysis is a weighted average of the costs of the various types of synthetic fuels that the market would find economical to produce. These costs were computed from costs assessed separately for liquid and gaseous synthetics. Table I-5 illustrates for the informational program case how estimates of synthetic liquids and gas costs were adjusted for the premium value of gas over oil and the fraction of synthetics that are gases. The premiums and fractions used were derived from the results of the SRI Energy Model sensitivity cases.

5. Cost Factors for Synthetic Fuel Capacity Expansion

The 1995 synthetic fuel costs shown in Table I-4 are nominal values that do not take into account the cost of rapid capacity expansion between 1985 and 1995. The greater the expansion, the greater the strain on secondary suppliers, on transportation facilities and on other support industries; except for some socio-economic and environmental effects, this added strain on the general infrastructure will be internalized by the synthetic fuel industry and increase its production costs. To some extent, the commercialization program will mitigate these expansion costs by providing some of the necessary infrastructure before 1985. As shown in Figure I-3, the larger the program the lower the costs of expansion. Note, for instance, that if there is no program, expansion beyond three million barrels per day is prohibitively expensive.

The curves in Figure I-3, when multiplied by the nominal 1995 costs shown in Table I-4, are the long-term marginal cost, or supply, curves used to compute the producer surplus derived from the second-generation plants.

6. Foreign Fuel Price

The price of imported fuel in both 1985 and 1995 depends very strongly on the state of the oil producers' cartel at the time. It is assumed that, if the cartel is weak, it has no control over the world price of fuel; rather, the price is set at a rather low level by market forces. On the other hand, if the cartel is strong, it can maintain its price at a higher level.

Because the productive capacity of synthetic fuel in 1985 will be relatively small regardless of program size and because only expensive first-generation plants will be in operation then the price set by the cartel in 1985 is independent of the synthetic fuel program. The 1985 imported fuel prices are shown in Table I-7. By 1995, however, synthetic fuel will be a potentially attractive alternative to imported fuel. The cartel, assuming that it is strong will then adjust its price according to the long-term cost of producing synthetic fuel. The dependence of the 1995 imported fuel price on the cost of synthetic fuel is shown in Figure I-4.

Table I-4

SYNTHETIC FUEL COSTS

Program	Forecast	Actual 1985 Cost	Forecast of 1995 Cost		Actual 1995 Cost
No Program 0 B/d	Expensive	23.56	22.44	High	28.54
				Medium	22.44
				Low	18.45
	Moderate	17.06	16.25		20.50
					16.25
					12.85
	Cheap	13.14	12.51		19.31
					12.51
					8.46
Informational Program 315,000 B/d	Expensive	23.56	20.40		23.46
					20.40
					17.34
	Moderate	17.06	14.77		16.99
					14.77
					13.29
	Cheap	13.14	11.37		14.21
					11.37
					8.75
Medium Program 930,000 B/d	Expensive	23.56	17.34		19.10
					17.34
					15.19
	Moderate	17.06	12.66		14.36
					12.66
					11.67
	Cheap	13.14	10.23		12.53
					10.23
					9.14
Maximum Program 1,605,000 B/d	Expensive	23.56	16.32		17.87
					16.32
					14.96
	Moderate	17.06	11.61		13.01
					11.61
					10.91
	Cheap	13.14	10.23		11.64
					10.23
					9.48

TABLE I-5

DEVELOPMENT OF SYNTHETIC FUELS ECONOMICS
(For Informational Program Case)

	Cheap	Nominal	Expensive
Synthetic liquids cost ($/bbl)	10.00	14.00	20.00
Synthetic gases cost ($/MMBtu)	2.25	2.75	3.75
($/bbl)	13.05	15.95	21.75
Premium for gas over oil ($/bbl)	0	.60	1.20
Adjusted cost of gas ($/bbl)	13.05	15.35	20.55
Fraction of synthetics that are gases	.45	.57	.73
Weighted cost of synthetic fuels ($/bbl)	11.37	14.77	20.40

TABLE I-6

CAPACITY EXPANSION COST FACTORS

	Expansion					
	0 million bbl/day	1 million bbl/day	2 million bbl/day	3 million bbl/day	4 million bbl/day	5 million bbl/day
No program	0.94	1.00	1.13	1.32	3.00	10.00
Informational program	0.90	0.96	1.05	1.16	1.30	1.61
Medium program	0.89	0.94	1.01	1.11	1.23	1.46
Large program	0.88	0.93	0.99	1.06	1.16	1.36

TABLE I-7

FOREIGN FUEL PRICES, 1985

	($/Barrel)		
State of Cartel	High	Medium	Low
Strong	$19.00	$15.00	$11.00
Weak	10.00	8.0C	6.00

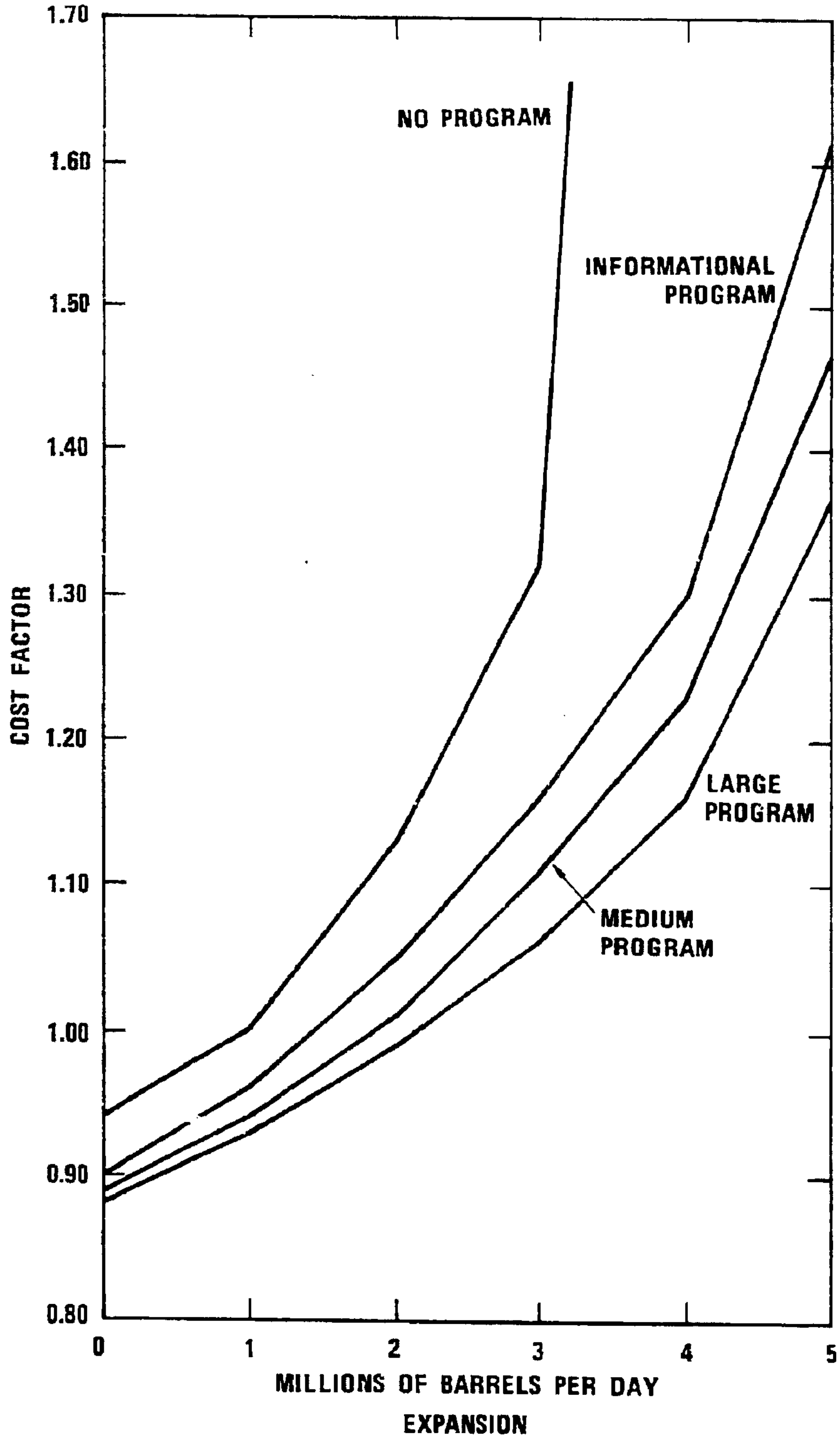


FIGURE I-3 SYNTHETIC FUEL EXPANSION COST FACTORS

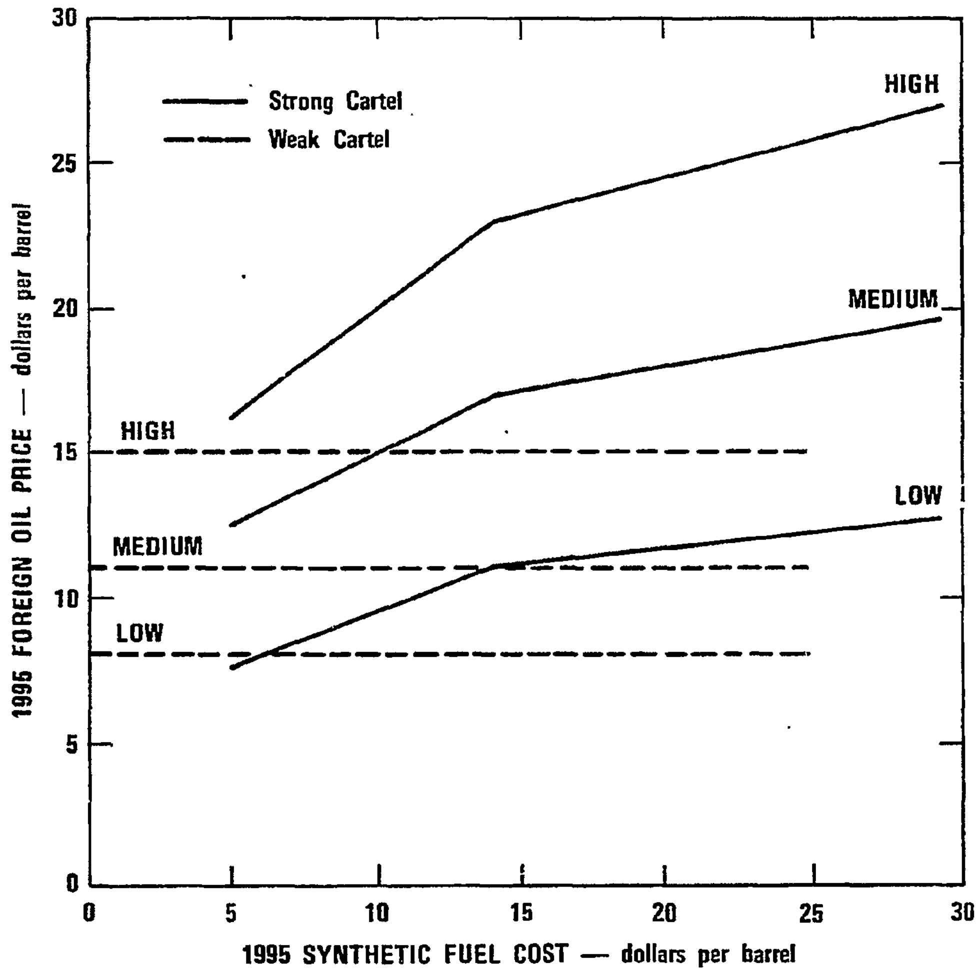


FIGURE I-4 1995 FOREIGN OIL PRICE

B. THE DECISION ANALYSIS MODEL

The expected benefit for each program alternative is determined by calculating the total benefit for each of the thousand paths through the decision tree, multiplying by the probability of the path and summing. For each path, the total benefit is calculated separately for the years 1985 and 1995 and weighted with the appropriate discount factors.

This section describes in detail how the total benefit is calculated for a given path through the tree. The first part describes the evaluation of the state variables and the remaining portion describes the calculation of the various components of benefit.

1. Evaluation of State Variables

For a given path through the decision tree, the following state variables are evaluated for 1985 and 1995 (refer to Figure I-5):

- Demand curve parameters: a,b,c
  - For 1985, from Table I-1
  - For 1995, from Table I-1, given the U.S. energy position.
- Synthetic fuel capacity: q_s
  - For 1985, from Table I-2, given the program level
  - For 1995, the sum of the 1985 capacity and the amount of capacity expansion from Table I-3, given the program level, the forecast of synthetic fuel cost, and the 1985 state of the cartel
- Market clearing price of synthetic fuel: p_s'. For 1985 and 1995, derived from the demand curve:

$$p_s' = \frac{a}{b+q_s} + c$$

- Synthetic fuel cost: p_s.
  - For 1985, from Table I-4, given the synthetic fuel cost forecast
  - For 1995, from Table I-4, given the program level, the synthetic fuel cost forecast, and the level of synthetic fuel cost

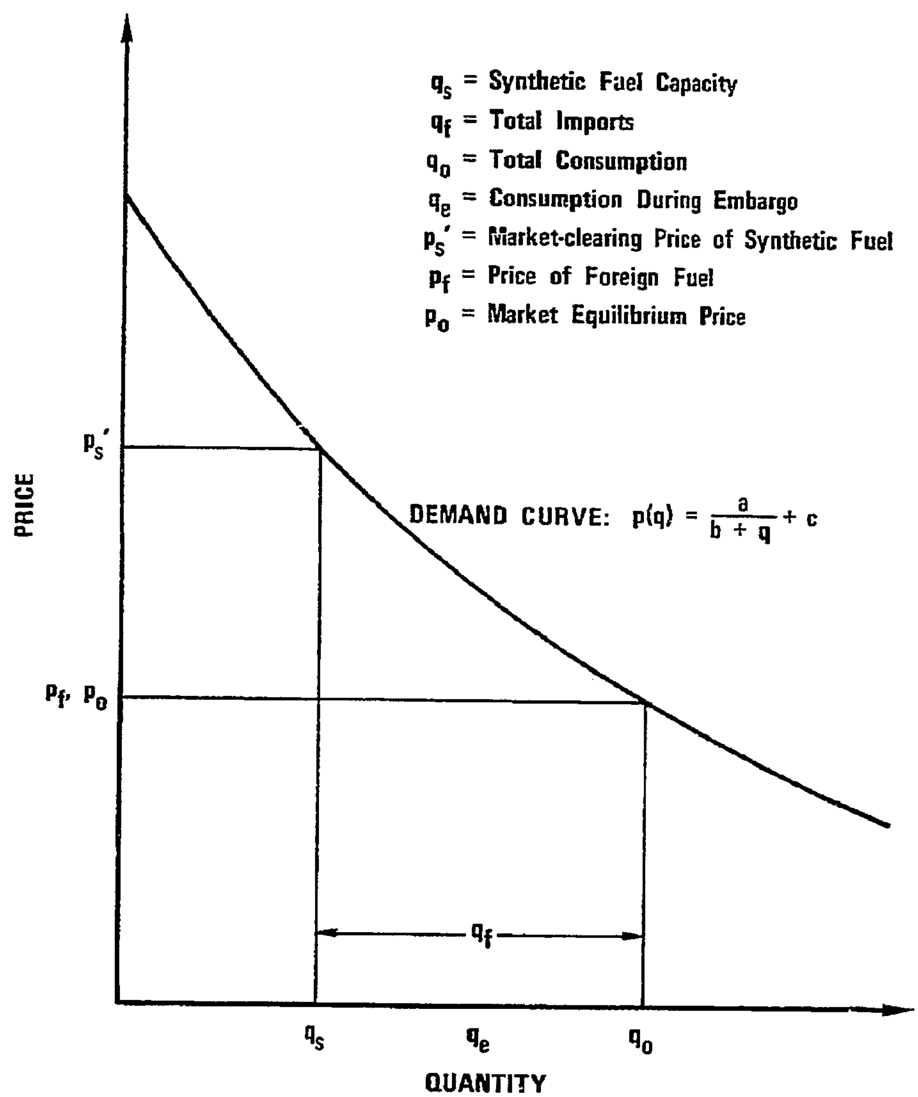


FIGURE I-5 INTERRELATIONSHIP OF STATE VARIABLES

- Foreign fuel price: p_f.
  - For 1985, from Table I-7, given the 1985 state of the cartel and the level of foreign fuel price
  - For 1995, from Figure I-4, given the 1995 state of the cartel, the synthetic fuel cost, and the level of foreign fuel price
- Market equilibrium price: p_o.
  - For 1985 and 1995, derived from:

$$p_o = \min(p_s', p_f)$$

- Total consumption of foreign and synthetic fuel: q_o.
  - For 1985 and 1995, derived from the demand curve:

$$q_o = \frac{a}{p_o - c} - b$$

- Total imports: q_f.
  - For 1985 and 1995, derived from:

$$q_f = q_o - q_s$$

- Total consumption during an embargo: q_e.
  - For 1985 and 1995, derived from

$$q_e = q_o - q_{f/2}$$

(This assumes that one-half of the imported fuel is subject to disruption during an embargo.)

Once values are specified for these state variables, all components of benefit can be calculated.

2. Calculation of Consumer Surplus

Refer to Figure I-6. Given a demand curve specified by the parameters a, b, and c, and given a market equilibrium price p_o of foreign and synthetic fuel, the consumer surplus is represented by the shaded area below the demand curve and above the horizontal line at p_o.

This area is determined as follows. The demand curve is given by the equation

$$p(q) = \frac{a}{b+q} + c$$

or

$$q(p) = \frac{a}{p-c} - b.$$

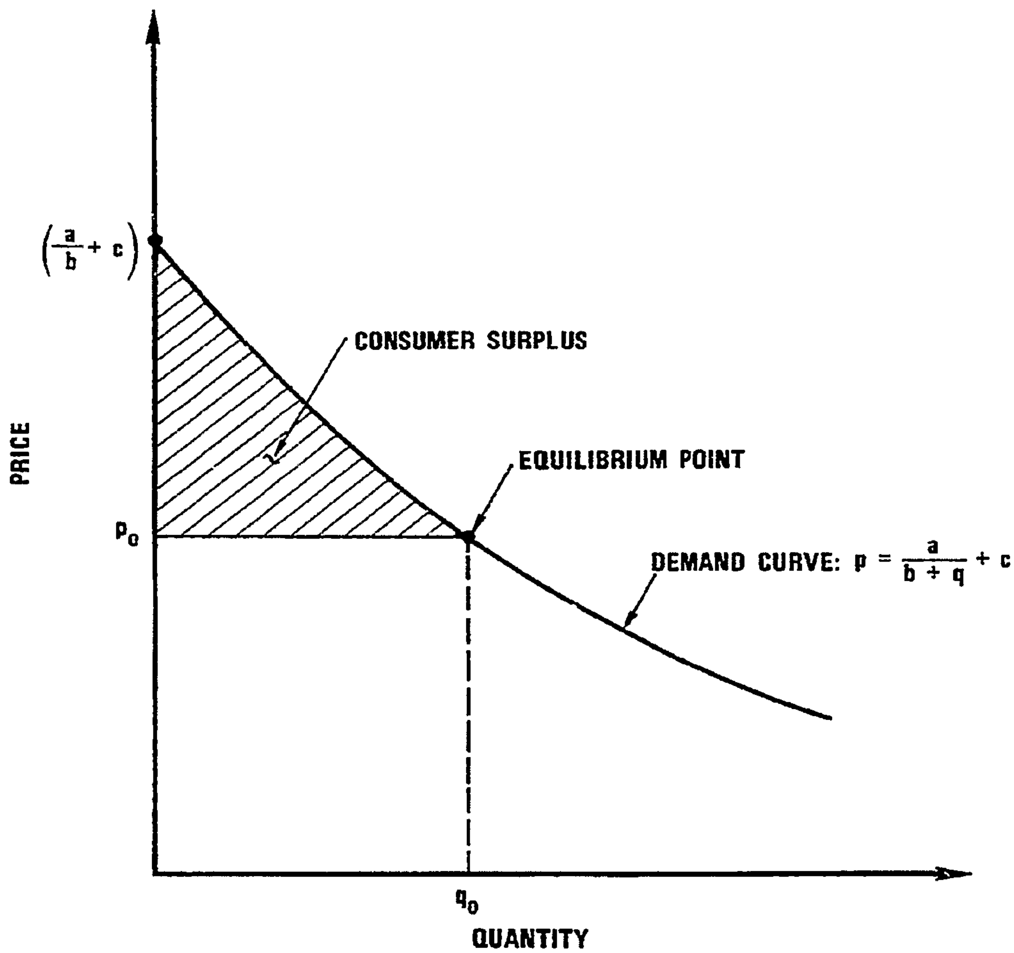


FIGURE I-6 CONSUMER SURPLUS

Then, the shaded area is:

$$C.S.(p_o) = \int_{p_o}^{(\frac{a}{b} + c)} q(p)dp$$

$$= \int_{p_o}^{(\frac{a}{b} + c)} (\frac{a}{p-c} - b) \quad dp$$

$$= \Big[a \ln(p-c) - bp \Big]_{p_o}^{(\frac{a}{b} + c)}$$

$$= a \ln(\frac{a}{b}) - a \ln(p_o - c) - b(\frac{a}{b} + c) + bp_o$$

$$C.S.(p_o) = a(\ln(\frac{a}{b}) - 1) - a \ln(p_o - c) + b(p_o - c).$$

3. Calculation of Expected Embargo Loss

Refer to Figure I-7. Given a long-term demand curve and a market price p_o of foreign and synthetic fuel, the pre-embargo equilibrium point is (p_o, q_o). During an embargo, the quantity of fuel available for consumption decreases abruptly to q_e. Because of short-term inflexibilities in consumption patterns, the equilibrium price p_e of fuel during an embargo is higher than the long-term demand curve indicates. In the analysis, we use a linear approximation of the short-term demand curve with a slope five times steeper than the slope of the long-term demand curve at the pre-embargo equilibrium point.

The loss of consumer surplus during an embargo is represented by the shaded trapezoidal area. This area is determined as follows. The long-term demand curve and its slope are:

$$p(q) = \frac{a}{b+q} + c$$

$$\frac{dp(q)}{dq} = - \frac{a}{(b+q)^2}$$

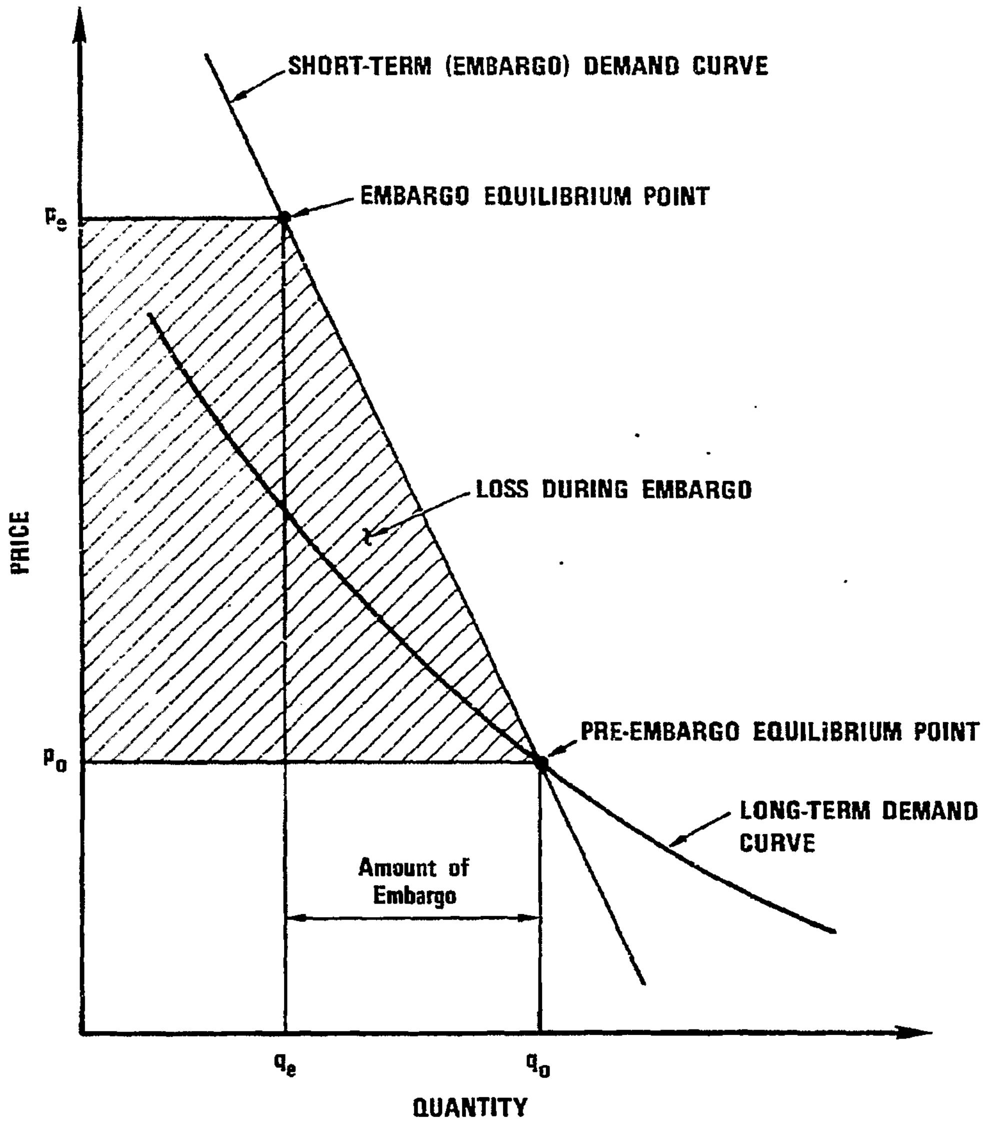


FIGURE I-7 EMBARGO LOSS

The slope $-k$ of the short-term demand curve is five times the slope of the long-term demand curve at the pre-embargo equilibrium point (p_o, q_o):

$$-k = -\frac{5a}{(b+q_o)^2}.$$

The short-term equilibrium price p_e during an embargo is:

$$p_e = p_o + k(q_o - q_e)$$

$$= p_o + \frac{5a(q_o - q_e)}{(b+q_o)^2}$$

Then, the trapezoidal area representing the loss of consumer surplus during an embargo is: $\text{Loss} = 1/2(q_o + q_e)(p_e - p_o)$

$$= 1/2(q_o + q_e)\,\frac{5a(q_o - q_e)}{(b+q_o)^2}$$

$$= \frac{5}{2}\,a\,\frac{(q_o^2 - q_e^2)}{(b+q_o)^2}$$

Given the probability p_r of an embargo during the year and an expected duration of an embargo of five months, the expected annual embargo loss is:

$$\text{E.L.} = -\left(\frac{5}{12}\right)(p_r)(\text{Loss})$$

$$\boxed{\text{E.L.} = -\left(\frac{5}{12}\right)(p_r)\frac{5}{2}\,a\,\frac{(q_o^2 - q_e^2)}{(b+q_o)^2}}$$

In the analysis, the probability of an embargo is given as $\frac{1}{10}$ in 1985 and $\frac{1}{20}$ in 1995.

4. Calculation of Producer Surplus

Refer to Figure I-8. Given a long-term supply curve for synthetic fuel, a fixed synthetic fuel capacity q_s, and a market price p_o, the surplus to the producers of synthetic fuel is represented by the algebraic sum of the shaded areas. The area for which the market price is above the supply curve is a positive contribution to producer surplus, while the area for which the market price is below the supply curve is a negative

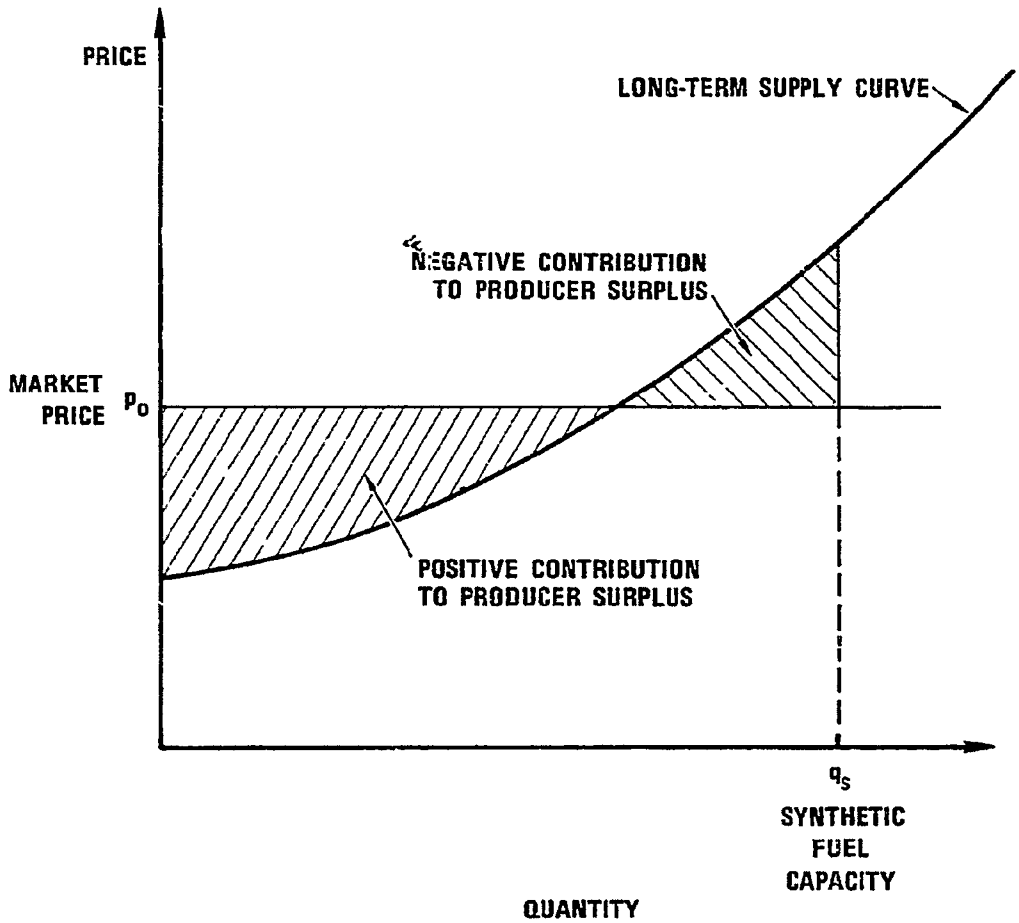


FIGURE I-8 PRODUCER SURPLUS

contribution. In the analysis, it is assumed that synthetic fuel is always produced at full capacity because the market price always exceeds the short-run marginal cost of production with capital costs fixed.

If the supply curve is denoted as $p_c\ (q)$, the producer surplus is given as:

$$S.P. = \int_o^{q_s} (p_o - p_c(q))dq$$

In the analysis, we use a piecewise linear approximation of the supply curve, denoted $p_c\ (q_i)$. The producer surplus is then calculated as the signed sum of trapezoidal and triangular areas, as follows:

$$S.P. = \sum_{i=2}^{N} (q_i - q_{i-1}) \frac{1}{2} [(p_o - p_c(q_i)) + (p_o - p_c(q_{i-1}))]$$

$$= \sum_{i=2}^{N} (q_i - q_{i-1})[p_o - \frac{1}{2} p_c(q_i) - \frac{1}{2} p_c(q_{i-1})]$$

where N is such that $q_N = q_s$, the synthetic fuel capacity.

The supply curve for plants built after 1985 is the product of the 1995 synthetic fuel cost p_s and the appropriate capacity expansion cost factor curve shown in Figure I-3. Letting $f(q_i)$ denote the expansion cost factor, we get the supply curve:

$$p_c(q_i) = f(q_i) \cdot p_s$$

The producer surplus from these plants is:

$$S.P. = \sum_{i=2}^{N} (q_i - q_{i-1})[p_o - \frac{1}{2} p_s[f(q_i) + f(q_{i-1})]] \ .$$

For plants built before 1985, the supply curve is assumed to be horizontal at the 1985 synthetic fuel cost P_{s85}, so the producer surplus from these plants is:

$$S.P. = (p_o - p_{s85}) \cdot q_{s85} \ .$$

5. Calculation of Environmental and Socio-Economic Costs

The non-internalized environmental and socio-economic cost of synthetic fuel production is assumed to be $.40 per barrel, so the total cost is:

$$EVC = -(.40)\ q_s\ .$$

6. Calculation of Total Discounted Net Benefit

The total net benefit in each of the years 1985 and 1995 is simply the sum of the consumer surplus, the expected embargo loss, the producer surplus, and the environmental and socio-economic costs in that year:

$$B_j = C.S._j + E.L._j + S.P._j + EVC_j$$

where j = 1985 or 1995.

The total discounted net benefit is determined by multiplying the benefit in each year by the appropriate discount factor and summing. The benefit in 1985 represents the annual benefit for the decade 1980-1990; similarly, the benefit in 1995 represents the annual benefit for the decade 1990-2000. For a 10% discount rate, the resulting discount factors are 4.20 for 1985 and 1.62 for 1995, so the total discounted net benefit is:

$$T.B. = (4.20)B_{1985} + (1.62)B_{1995}$$

This total discounted benefit, multiplied by the path probability, contributes to the expected discounted net benefit of the particular program alternative.

C. CALCULATION OF BENEFIT FOR A SAMPLE PATH

As an example, consider the following path through the decision tree:

- Informational program alternative
- Nominal synthetic fuel cost forecast
- Strong 1985 cartel
- Nominal 1985 foreign fuel price
- Nominal 1985 synthetic fuel cost
- Strong 1995 cartel
- Nominal 1995 foreign fuel price
- Moderate 1995 U.S. energy position

Using the sequence of calculations described in Section 2 above, we determine the total discounted net benefit for the path as described below.

1. Calculation of 1985 Benefits

a. Evaluation of State Variables

a =	1888.875	
b =	19.893	(Table I-1)
c =	-69.000	
q_s =	.115 billion bbl/year	(Table I-2)
p_s' =	\$25.41	(Derived from demand curve)
p_s =	\$17.06	(Table I-4)
p_f =	\$15.00	(Table I-7)
p_o =	\$15.00	(Derived from p_s', p_f)
q_o =	2.59 billion bbl/year	(Derived from demand curve)
q_f =	2.48 billion bbl/year	(Derived from q_o,q_s)
q_e =	1.36 billion bbl/year	(Derived from q_o,q_f)

b. Calculation of Consumer Surplus

$$C.S. = a(\ln(\frac{a}{b})-1) - a \ln(p_o-c) + b(p_o-c)$$

C.S. = $13.63 billion/year.

c. Calculation of Expected Embargo Loss

$$E.L. = -(\frac{5}{12})(\frac{1}{10})(\frac{5}{2} a) \frac{(q_o^2-q_e^2)}{(b+q_o)^2}$$

E.L. = -$1.90 billion/year.

d. Calculation of Producer Surplus

$$S.P. = (p_o-p_s)q_s$$

S.P. = -$0.24 billion/year.

e. Calculation of Environmental and Socio-Economic Costs

$$E.V.C. = -(.40)q_s$$

E.V.C. = -$0.04 billion/year.

f. Calculation of Total 1985 Benefit

$$B_{1985} = C.S. + E.C. + S.P. + E.V.C.$$

B_{1985} = $11.44 billion/year.

2. Calculation of 1995 Benefits

a. Evaluation of State Variables

a =	809.910	
b =	15.596	(Table I-1)
c =	-23.946	
q_s =	.846 billion bbl/year	(2.315 million bbl/day), (Tables I-2, I-3)
p_s' =	\$25.31	(Derived from demand curve)
p_s =	\$14.77	(Table I-4)
p_f =	\$17.13	(Derived from Figure I-4)
p_o =	\$17.13	(Derived from p_s', p_o)
q_o =	4.12 billion bbl/year	(Derived from demand curve)
q_f =	3.27 billion bbl/year	(Derived from q_o, q_s)
q_e =	2.48 billion bbl/year	(Derived from q_o, q_f)

b. Calculation of Consumer Surplus

$$C.S. = a(\ln(\frac{a}{b})-1) - a\ln(p_o-c) + b(p_o-c)$$

C.S. = \$20.60 billion/year.

c. Calculation of Expected Embargo Loss

$$E.L. = -(\frac{5}{12})(\frac{1}{20})(\frac{5}{2}a)\frac{(q_o^2-q_e^2)}{(b+q_o)^2}$$

E.L. = -\$1.17 billion/year.

d. Calculation of Producer Surplus

The capacity expansion is two million barrels per day (Table I-3). The producer surplus from the plants built after 1985 is:

$$S.P._1 = (.365)[p_o - \frac{1}{2} p_s (0.90+0.96)]$$

$$+(.365)[p_o - \frac{1}{2} p_s (0.96+1.05)]$$

$$S.P._1 = \$2.07 \text{ billion/year}$$

The producer surplus from plants built before 1985 is:

$$S.P._2 = (p_o - p_{s85}) \cdot q_{s85}$$

$$S.P._2 = \$0.01 \text{ billion/year.}$$

Total producer surplus is:

$$\underline{S.P. = \$2.08 \text{ billion/year}}$$

e. Calculation of Environmental and Socio-Economic Costs

$$E.V.C. = -(.40)q_s$$

$$\underline{E.V.C. = -\$0.34 \text{ billion/year.}}$$

f. Calculation of Total 1995 Benefit

$$B_{1995} = C.S. + E.L. + S.P. + E.V.C.$$

$$\underline{B_{1995} = \$21.17 \text{ billion/year.}}$$

3. Calculation of Discounted Net Benefits

$$T.B. = (4.60)B_{1985} + (1.62)B_{1995}$$

$$\underline{T.B. = \$82.34 \text{ billion}}$$

(Path probability = 0.0125)

D. ENVIRONMENTAL AND SOCIO-ECONOMIC ISSUES

The cost ascribed to synthetic fuels should include not only the economic factors such as labor and capital goods, but also such consequences as air pollution, water pollution, land disruption, and rapid regional growth. Therefore, a social cost was added to the economic cost of synthetic fuels to reflect values that might be placed on the environmental and socio-economic consequences resulting from a Synthetic Fuel Commercialization Program. For the decision analysis it has been assumed that costs of meeting pollution standards and providing for some degree of regional infrastructure are internalized in the economic costs, since the cost of control programs will be reflected in the market price of synthetic fuel products. The residual emission levels remaining and socio-economic impacts from rapid regional development give rise to social — or external — costs. In some cases these externalities could be reduced by using a more effective, more expensive control strategy. However, this change would result in a higher internal cost for the synthetic fuel.

Environmental costs include air emissions, water quality and availability, and disturbances to land and associated flora and fauna. Emission of sulfur oxides and nitrogen oxide are ascribed costs based on air pollution damages as cited in recent National Academy reports. The cost associated with other air emissions was assumed to be small in comparison. Water withdrawals associated with western coal and oil shale development are assumed to result in increased salinity in major river systems. Increased salinity and other water quality issues are assessed in terms of dollars per acre-foot of water used. Land disturbance, including effects on vegetation and fauna and aesthetic impact, is included by assessing a dollar value per acre of disturbed land. The cost of land rehabilitation and revegetation is assumed to be already included in the economic cost of coal and shale mining. Environmental cost calculations for representative synthetic fuel processes are given in Table I-8. The basis for these estimates is presented in Appendix E.

Socio-economic impacts and health and safety considerations are other examples of social consequences that may not be included in the economic cost of synthetic fuels. Synthetic fuel processing and associated activities will create employment, and to the degree that these jobs will promote economic growth, the program may have a positive benefit. On the other hand, many of the synthetic fuels facilities may be built in sparsely settled regions, necessitating rapid creation of public services and other infrastructure, and perhaps involving social dislocation and conflicts in life style between the incoming population and the present inhabitants of the region. Rough judgments of the magnitude of the socio-economic impacts have been made, and the resulting values are shown in Table I-8. Discussion of the socio-economic impact and possible methods to insure the provision of services and infrastructure are discussed in Appendix D.

Table I-8

SOCIAL COSTS FOR REPRESENTATIVE SYNTHETIC FUEL TECHNOLOGIES
(Cents per Barrel Equivalent)

Category of Social Cost	Oil Shale			High Btu Gas Plant (Using Powder River Coal)		
	Low	Normal	High	Low	Normal	High
Environmental Costs						
Air Emissions						
Sulfur Oxides	1	8	21	5	19	47
Nitrogen Oxides	3	9	30	2	5	16
Water Depletion	0	1	13	0	3	42
Water Quality	0	2	23	1	11	56
Land Surface Alteration	0.1	1	11	0.1	1	8
Total* Environmental Costs	12	21	56	21	39	106
Socio-economic Impact	-14	7	70	-20	10	90
Occupational Health and Safety	6	12	30	0.3	0.6	5
Total* Social Cost	17	40	114	16	50	160
Values Used for Sensitivity Analysis:	0	40	100	0	40	100

*Totals for low and high cases are computed by taking the square root of the sum of the squares of deviations from nominal values.

Health and safety of the synthetic fuel process workers may also be considered a possible externality. Extrapolation from coal mining experience and standard assumptions for valuing fatal and non-fatal accidents provide the basis for the assessments shown in Table I-8. Discussion of the basis for these assessments is given in Appendix E.

If social costs are found to be high it is assumed that some mitigating strategies may be taken to reduce them. For example, if sulfur oxides are found to cause damages at the high rate of 25 cents per pound of sulfur oxide emitted instead of the nominal estimate of 10 cents, imporved scrubber technologies may be used to reduce sulfur emissions. These technologies will add to the economic cost of synthetic fuels but should reduce the total of economic and social cost. For this reason we have used the value of $1.00 per barrel as the upper limit for sensitivity analysis. It should be noted that $1.00/barrel represents about $18 million annually for a 50,000 barrel/day plant, or $365 million annually for a one million barrel per day program. The nominal value used for environmental and socio-economic externalities is $0.40 per barrel of oil equivalent, and a lower value of $0.00 has been used in the sensitivity analyses.

E. SOCIO-ECONOMIC IMPACTS

One effect of synthetic fuels programs should be to provide additional employment, which is a desirable social objective. It is not known to what extent a synthetic fuel program would create new jobs as opposed to displacing a limited supply of skilled workers from other productive activity. It seems reasonable to assume that some new jobs would be created, directly or indirectly as job openings occur due to workers leaving to take employment in a synthetic fuel industry.

In sparsely settled western areas, rapid growth may accompany the development of a synthetic fuel industry, leading to additional expenditures needed to provide infrastructure and public services. To the extent that these costs are not reflected already in the economics of synthetic fuel program they should be included as externalities. There may also be costs associated with social disruption and conflict attendant with rapid growth and cultural difference between the original inhabitants of the region and the population influx caused by synthetic fuel development.

As a rough summary of the order of magnitude of these effects, the assumptions shown in Table I-9 were used to compute a socio-economic externality cost for the cost benefit analysis. These assumptions plus the employment figures from the Draft Environmental Impact Analysis were used to compute the socio-economic impact costs listed in Table I-8.

TABLE I-9

Estimate of Socio-Economic Externality Effects

low case:	operating workers	$2000 net benefit per worker
	construction workers (over life of plant)	200 net benefit per worker
nominal estimate:	operating workers	$1000 net cost per worker
	construction workers (over life of plant)	100 net cost per worker
high case:	operating workers	$10,000 net cost per worker
	construction workers (over life of plant)	1,000 net cost per worker

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